AIDS

TO

ZOOLOGY AND COMPARATIVE ANATOMY.

London:
REPRINTED FROM THE "STUDENTS' JOURNAL"
BY
BAILLIÈRE, TINDALL & COX.

AIDS

TO

ZOOLOGY AND COMPARATIVE ANATOMY.

BY

MAJOR GREENWOOD, Junr.,

M.R.C.S., L.R.C.P., Lond., Honours in Zoology, University of London, &c.

LONDON: BAILLIÈRE, TINDALL & COX

KING WILLIAM STREET, STRAND.
DUBLIN: FANNIN & CO., GRAFTON STREET.
EDINBURGH: MACLACHLAN & STEWART, SOUTH BRIDGE.
GLASGOW: A. & W. STENHOUSE, COLLEGE GATE.
NEW YORK: PUTNAM & SONS.

1883.

PREFACE.

THE object of this little book is to form a handy and compact epitome of the chief points in the comparative anatomy of the Invertebrata and Vertebrata, and in this respect I think it will be found very useful to the student about to present himself for any of the now numerous examinations in Zoology of the present day. I had designed it more especially to meet the requirements of the P. Sc. Exam. at the London University, but as the greater includes the less, and I consider there are few elementary examinations where more is required of the candidate than at those conducted by the University of London, I trust my AIDS TO ZOOLOGY will meet the requirements of most of the metropolitan and provincial examining boards in this subject.

In the first section of my book I have briefly touched upon a few of those important questions

and generalisations that every student of Biology is expected to be more or less conversant with, and I think the views I have there put forward are in accordance with those of the most eminent authorities.

Lastly, I may add that I have to express my best thanks to Dr. Edward Aveling, for the valuable assistance I have derived in the compilation of these "AIDS" from his lectures on Comparative Anatomy, delivered at the Medical School of the London Hospital; and at the same time, I would also acknowledge my indebtedness to the published works on Zoology, by Professor H. Alleyne Nicholson, to whom I would refer any student desirous of dipping more deeply into this most important and interesting subject.

M. GREENWOOD, JUN.

June, 1883.

CONTENTS.

AIDS TO ZOOLOGY AND COMPARATIVE ANATOMY.

Zoology is one of the two divisions into which Biology is usually divided.

Biology, derived from two Greek words (βιος, life; λογος, treatise), signifies the study of the phenomena of life; and, as Science has shown that all life may be relegated to one of two large divisions—known respectively as the Animal and Vegetable Kingdoms—and that in these only are found manifestations of the phenomena which we consider the special attribute of life, Biology naturally becomes divisible into two sections, one dealing with vegetable life, to which we give the name Botany, the other with animal life, which we call Zoology.

It is this latter only that we wish to study here, our object being to inquire into life as seen in the animal kingdom; but, before confining ourselves to this, a few principles will have to be discussed, a general idea of which is necessary before we can enter upon the study of any department of biology.

I. *Nature of Life.*—What Life is, how it originates, whether always the product of pre-existing life, or whether it arises *de novo* from matter under certain conditions, has never been satisfactorily determined. It is, perhaps, best to regard it as simply a "ten-

dency exhibited by certain forms of matter, under certain conditions, to pass through a series of changes in a more or less definite and determinate sequence." It is always found in connection with a form of matter known as protoplasm, which is a substance composed of carbon, oxygen, hydrogen, and nitrogen, and is almost identical with albumen, or white of egg. It contracts under the influence of electricity, and undergoes a peculiar coagulation at a temperature of 104°—120° F.; it must also be placed under certain external conditions to manifest vitality.

(i.) A temperature ranging from near 32° F. to 120° F.

(ii.) The presence of water.

(iii.) Nearly always the presence of free oxygen is absolutely necessary, although there are some apparent exceptions in the case of certain fungi.

The non-fulfilment of any of these conditions for a length of time gives rise to a cessation of all vitality, to which the term death is usually applied.

I may here remark that there are certain apparent exceptions to this in many of the lower forms of life, exemplifying in a striking manner the pertinacity with which these lowly organisms retain their vitality when many of the above fundamental conditions are withheld: they appear to have the power of existing in a dormant or potential condition for an almost indefinite time. As an instance of this, we have the familiar example of seeds that have been kept for years, and have yet germinated on being placed under suitable conditions, even, as in the case of some taken from

tombs, when the period they have been lying dormant might be estimated by centuries.

In the animal kingdom certain small beings of a comparatively high grade of organization, belonging to the order Rotifera, or Wheel-animalcules, have been dried and kept in this state for years, and on the addition of a little water have manifested unmistakable vitality.

This extreme tenacity of life is, of course, more marked as we descend in the scale: the lowlier the organism the more pains Nature seems to have taken to preserve it, or its offspring, in the struggle for existence.

The great power of resisting destroying agencies shown by many of the lowest forms of life would also tend to support the doctrine of the Panspermists, or of those who affirm there is no such thing as spontaneous generation, and that, wherever life is manifested, its germs are always present in the vicinity waiting for conditions favourable to their development.

II. *Vital Force.*—This is the term given to a peculiar property possessed by living matter, by virtue of which it is able to act on certain forms of inert matter and alter its physical state in various ways; this is really the essence of life itself, for it is by means of this power that matter endowed with life is able to select from the surrounding medium nourishment wherewith to form its tissues, assimilating what is suitable and rejecting what is hurtful, and in this way go through the cycle of changes that constitutes its own particular life.

Much of this "vital force" the researches of science during late years have shown to be simply due to ordinary chemical laws, but much still

remains altogether unaccounted for by our present knowledge of chemistry, physiology, or any other natural science; at the same time we must not forget that the term "vital force" is but a convenient expression for a power we at present know very little about.

III. *Organized and Unorganized Bodies.*—All matter may be divided into these two classes. To matter that is inert and, as far as we can judge, has always been inert, we apply the latter term; the former we give to matter that supports life, is, or has at any time been, the product of life.

The following physical characters distinguishing the two may be briefly enumerated:—

Unorganized bodies are composed of *many* elements; when these are combined, their combinations are limited to a *small* number of elements; they are usually made up of *homogeneous* parts bearing no fixed relation to one another; they are either without form or *amorphous*, or they are crystalline, and, in that case, invariably bounded by *plane surfaces and straight lines.* When they increase in size, as in the case of crystals, it is by a process of *accretion* or addition to the exterior; and they exhibit no actions that are not explained by chemical or physical laws.

Organized bodies, on the other hand, are made up of *few elements;* but these, in their combinations, are *most complex* and far more unstable than those of the other class; the elements of water (H_2O) are invariably present, and they are prone to spontaneous decomposition. Organized bodies, again, are made up of *heterogeneous* parts that usually have relations among themselves *more or less definite;* they present *convex and concave* surfaces, and are

bounded by *curved lines.* When they increase in size, it is by a process of *intus-susception*, or addition to the interior; and it is to this increase only that the term *growth* can rightly be given. Lastly, they go through cyclical or periodic changes; that is to say, they undergo "a series of changes in a more or less definite sequence."

With regard to the last two characteristics, they are, of course, only applicable to *living* organized bodies, and the cyclical changes usually correspond with what we know as the *life* of the organism, and are divisible into three stages—(i.) *Growth*; (ii.) *Maturity*; (iii.) *Decadence.*

IV. *Difference between Animals and Plants.*—This distinction, which at first sight might to many appear scarcely a difficult one when taking into consideration only individuals of the higher grades of each—for there are few, I take it, who would have much trouble in distinguishing between a tree and an elephant—nevertheless, when we go back to the dawn of life, and examine the structures and conditions of life as seen in the lowest members of the animal and vegetable kingdoms, we have before us a problem by no means easy of solution,

"Natura non habet lineas," and we must at once acknowledge that, as far as Science at present teaches us, we have no means of drawing a line between them. At the starting-point of animal and vegetable life, we are confronted by a series of organisms which might be referred with equal justice to either kingdom, as their distinguishing qualities belong as much to one as to the other; or, again, we meet with organisms that during one period of their existence are characterized by animal attributes, at another by vegetable; for instance, there are certain organ-

isms in early life that have the power of locomotion, which is essentially an animal function, while at a later period they become fixed and stationary.

To meet difficulties like these several eminent naturalists have proposed an "*intermediate kingdom*" for the reception of doubtful members, that can be classed as neither animal nor vegetable.

Having now clearly premised that the student must not expect to meet with any fine line of demarcation between animal and vegetable life—that in their lowest types these two kingdoms more or less approximate—we will next proceed to briefly enumerate what are usually reckoned the distinguishing characteristics of plants and animals. They may be discussed under the following heads :—

(*a.*) *Chemical Composition.*—In the composition of plants we find a preponderance of *ternary* compounds, that is, of compounds made up of the three elements, carbon, hydrogen, and oxygen, such as sugar, cellulose, starch, &c. *Nitrogenized* compounds, on the other hand, are more frequently found in animals. The presence of the green colouring matter, *chlorophyll*, is nearly always distinctive of vegetable life.

Exceptions.—Cellulose has been detected in the outer covering of certain Ascidians. Glycogen, a product of the liver in mammals, is nearly identical with the hydrated starch of plants. Chlorophyll has been found in certain animals.

(*b.*) *Motor Power.*—Although as a rule this is very distinctive of animals, it is nevertheless true that many undoubted animals are permanently fixed or attached to some foreign object throughout the whole term of their existence ; at the same time, many organisms that are as undoubtedly vegetable pass their early life

provided with means of locomotion, which they freely use, becoming fixed and stationary only on reaching maturity.

The locomotive power exhibited by Diatoms and Desmids, moreover, does not admit of being rigidly separated from the movements of animals.

(*c.*) *Nature of Food.*—It is here we have the best means of distinguishing animals from plants; the nature of their food will almost invariably afford us the means of deciding in which kingdom a doubtful organism should be placed. All plants are endowed with the power of converting inorganic matter into organic, for this is one of their special uses in nature. Speaking broadly, their food consists of such compounds as carbonic acid (CO_2), ammonia (NH_3) and water (H_2O), with small quantities of some mineral salts; from these, and from these only, they are able to elaborate the protoplasm which constitutes the physical basis of life.

No known animal, on the other hand, can convert inorganic into organic matter, but must be dependent in this respect on plants, as it is probable all animals require ready-made proteinaceous matter for the maintenance of their existence.

Hence, to summarize:

(i.) Plants take in as food *simple* bodies, and manufacture them into *complex* bodies.

(ii.) Plants are the *manufacturers* in nature, animals the great *consumers.*

Again, before leaving this subject, we may notice two other distinctions in the nature of the food used respectively by animals and plants. As the latter have no special aperture for its admission, or stomach for its reception, their food must consist partly of gaseous material, and partly of matter

held in solution; almost all animals, on the contrary, are able to digest solid particles, and are usually furnished with a special aperture and body cavity for its reception.

We must here except certain parasitic worms that live entirely by absorption of organic fluids by the body surface, also certain Protozoa of the class Gregarinidæ.

Lastly, as an almost invariable rule, plants decompose carbonic acid gas (CO_2), setting free oxygen, while animals absorb the oxygen and emit carbonic acid. Plants, therefore, are the great purifiers of the atmosphere, and help to keep it in a state fit to support animal life.

Certain fungi, again, appear to be exceptions to this rule.

V. *Differences between different Animals.*—If we consider for a moment how animals can differ among themselves, we shall at once come to the conclusion that, strictly speaking, they can only differ in two ways:

(i.) In form or structure, that is, morphologically (μορφὴ, form).

(ii.) In the manner in which they perform their vital functions, or physiologically.

It may be stated that the vital functions of organisms are usually classified under three heads:

(*a.*) *Functions of nutrition*, or those that are necessary for their growth and maintenance.

(*b.*) *Functions of reproduction*, which secure their perpetuation. (These two are often known as the functions of organic or vegetative life, being common to both plants and animals.)

(*c.*) *Functions of correlation.*—These include those functions by which the external world is brought into relation with the organism, such as sensation, voluntary motion, and the like.

Now, as we have just seen that animals can only differ among themselves morphologically, that is, structurally, or physiologically, we may proceed to investigate these differences under the heads of *Specialization of Function* and *Morphological Type.*

(*a.*) *Specialization of Function.*—It must be premised of all animals that they nourish themselves, reproduce their like, and have some relations with the external world. Now, as it is self-evident that, as far as they themselves are concerned, all perform the first two functions equally well, their existence being essentially dependent on it, there can be no distinction between them arising from the greater or less perfection with which these first two are performed. It is only when we come to the third that we have any means of discriminating between animals by the amount or perfection of the functions they individually perform.

Nevertheless, although nutrition and reproduction are accomplished with equal perfection by all, the manner in which this result is brought about differs much in different animals. Taking the function of nutrition, for example, we find that in the lowest Protozoa, a small mass of protoplasm, with no mouth, stomach, or any other organ, is able to select matter from the external world, reject the effete, and assimilate the nutritive ; here, plainly, the whole surface of the body must act as a stomach in addition to its other functions. If we go a step higher in the scale, we find that Cœlenterate animals, though, in most other respects, as rudimentary as

the former, instead of employing their whole body surface as a stomach, shut off a portion of it for that use, forming what is known as a somatic cavity. Here it is manifest that, in the case of the Cœlenterata, specialization of function has advanced a step; a division of labour has taken place; what before was done by a single organ, has now a special adaptation of a part of it for a special purpose; and so on, we find, throughout the animal kingdom, Specialization of function advances step by step in nutrition, reproduction and correlation, from the lowest to the highest grades, forming a certain and satisfactory means of classification.

What some animals require many organs to accomplish, may be done with as much completeness in others by a far simpler arrangement; and, beginning with the latter class, as we ascend in the scale, we find the essential difference between the higher and lower animals is, that the higher we get the more and more do we find special organs developed for special functions, or an increase in what is known as the specialization of function.

(*b*.) The next point in which one animal may differ from another is in its *Morphological Type*, or in the fundamental plan upon which it is constructed.

It is very worthy of note that, innumerable as are the animals at present living upon the earth, and numberless as they have been in the past ages of its existence, all these myriad forms, both of the present and of the past, are shown by Science to be referable to but *six fundamental types of structure*, technically called sub-kingdoms of the animal world. They are known as the *Protozoa*, *Cœlenterata*, *Mollusca*, *Annuloida*, *Annulosa*, *and Vertebrata*.

As, therefore, all forms of animal life comprise but six distinct morphological types, it necessarily follows

that large numbers of them must agree with one another in this respect, so that our chief means of classifying them individually must always be the amount of specialization of function shown by each.

Huxley has well defined every animal to be the resultant of two tendencies, the one morphological, the other physiological.

VI. *Von Baer's Law of Development.*—This simply enunciates as a law what we have just been discussing; that the *progress of development is from the general to the special;* that is, the higher we get in animal life the more do we find a physiological division of labour, or special organs for special purposes, instead of a single organ performing a variety of functions.

VII. *Homology and Analogy.*—When organs are constructed on the same plan they are *homologous;* when they perform the same functions they are *analogous:* for example, the wing of a bird and the arm of a man are homologous, but not analogous, as they serve two distinct purposes, whereas the wings of birds and insects are analogous, both serving for the purpose of flight, but are certainly not homologous.

VIII. *Homomorphism.*—This term is made use of when organisms have a *primâ facie* resemblance, or appear externally similar, but differ widely on internal examination.

IX. *Correlation of Growth.*—This expresses an empirical law, that certain structures always occur in association with one another, and never apart.

All animals that possess *two* condyles on their occipital bone have *non-nucleated blood corpuscles,* and *suckle* their young. All *ruminant* animals have *cleft*

feet. All *white* cats with *blue* eyes are at the same time *deaf.*

Although there is no reason, as far as we at present know, why the above-mentioned conditions should always occur in association, it is extremely unlikely these remarkable coincidences are accidental.

X. *Reproduction.*—This is the process by which new individuals are generated, and although it is accomplished in various ways and by various means, it may be considered essentially under two heads:—

(*a.*) Sexual reproduction.

(*b.*) Non-sexual reproduction.

Sexual Reproduction.—This is always the way in which the higher animals are reproduced, and seems, indeed, more or less necessary for the maintenance of all life *in perpetuo;* for, in many instances in which non-sexual reproduction occurs, we shall still find, every now and again, processes of generation in these that are more or less analogous to the higher form.

Sexual reproduction essentially consists in the formation of two distinct elements, a *germ cell* and a *sperm cell,* and it is by the union of these that a fecundated ovum, or *individual in embryo,* is generated.

In the higher forms of life the germ cell is produced by one individual, the female; the sperm cell by another, the male; but in the case of many organisms a single individual will develop both, when it is said to be hermaphrodite or monœcious, the former being called diœcious. In many monœcious organisms, however, their manner of propagation is really diœcious, the reciprocal union of two individuals being often necessary for the production of their young.

This is also very notably seen in the case of many plants, where self-fecundation may, and certainly does, occur, nature having put a bar on perpetual self-fertilization, and requiring at intervals the influence of another individual.

Non-sexual Reproduction. — Among the lower animals there are other forms of generation of an asexual character, that is, without any union of germ and sperm cell; but these, as we shall see, are really modifications of growth, and very rarely is it that a true individual is produced otherwise than sexually.

Among asexual forms of reproduction the following may be considered :—

(i.) *Gemmation and Fission.*—The former consists in the production of buds on the exterior or interior of the organism, which, after a time, are developed into independent beings, which may remain permanently attached to the parent organism (continuous gemmation), or may become detached (discontinuous gemmation).

The simplest form of gemmation is seen in the power possessed by some animals of reproducing parts of their bodies accidentally lost, as seen in the case of certain Crustaceans ; the product of gemmation here, however, is in no sense a new being (zoöid).

The most usual form of so-called gemmation is seen in the natural order Foraminifera. The animals of this class consist merely of small masses of sarcode (σάρξ, flesh; οιδος, like) or protoplasm; at certain periods small processes or projections arise from these bodies, which afterwards increase in size, and resemble, in all respects, the parent to whose sides they are attached ; other gemmæ in turn are produced from these, so that in time a large composite

organism arises, consisting of an aggregation of organic parts (zoöids); this is continuous gemmation: here it is plain the various zoöids are but remotely independent, and instead of a true reproductive process, we have rather a vegetative repetition of similar parts.

As an instance of discontinuous gemmation, where the buds are thrown off the parent, and pass an independent existence, the common fresh-water Polype or Hydra will furnish a good example.

Fission is simply another kind of gemmation, where a portion of the original body is subdivided without any buds being produced; it may be of a continuous, as in many corals, or discontinuous character, as in certain Hydrozoa.

It may now be advisable to say a few words as to the precise meaning of the term "individual" from a zoological point of view: an *individual* is the *total result of the development of a single ovum*. Now, in the case of the higher animals, the result of the development of a single ovum is but *one* animal, and one only, but in the case of others of an inferior grade—the sea-mat, for example—the first product of the ovum is but a *small* portion of the future individual, known as a zoöid, that develops buds, and soon produces other zoöids, so that eventually we have a large and composite colony, which really constitutes the individual; although these zoöids may, perhaps by a true generative process, give rise to fresh individuals. Again, as in the case of the Hydra, many of these zoöids may become detached, and form other colonies; they will still, nevertheless, strictly speaking, be regarded as forming part of the original individual.

Internal gemmation is the term given to reproduction by buds produced in the interior of the

animal, as in certain Polyzoa. These buds are known as stato-blasts, and lie loose in the cavity of the body till the death of the parent, when they develop into the adult form.

XI. *Alternation of Generation.*—This is the term given to a very curious set of phenomena met with in certain animals—the Campanularia, for example. It alludes to the fact that in these there is an alternation in the products of the primitive ovum ; by gemmation *two* sets of zoöids are produced, one of which is destitute of sexual organs, and is capable of performing no other function than that of nutrition, while the chief function of the other is the perpetuation of the species. It is singular, also, that in the former case the zoöids all resemble one another and the parent, whereas in the latter they are often quite unlike, probably on account of the difference of their functions.

At first sight this curious mode of reproduction seems difficult of comprehension ; the name itself is misleading, as it is not true alternation of generation, but an alternation of generation with gemmation. Perhaps the easiest way of understanding it is to regard the nutritive and reproductive zoöids (otherwise known as trophosome, *τρέφω*, I nourish ; and gonosome, *γονή*, seed,) as but integral parts of one organism, the former being the representative of the nutritive, the latter of the reproductive organs of the higher animals ; and this view may be adhered to, whatever the complexity of the ultimate zoological individual. In this way we are able to see a transition from the asexual reproduction of lowest organisms to a true sexual process—a distinct advance in the specialization of the reproductive function.

Alternation of generation occurs chiefly among

the *Hydrozoa*, but is seen also in many *Entozoa*, and in some *Tunicata* (Molluscoida).

XII. *Parthenogenesis* (παρθένος, virgin; γένησις, birth) implies a virgin birth, or a production of new individuals from virgin females, without the intervention of the male. This, like spontaneous generation, must still be regarded as a *questio vexata*; being apparently contrary to natural law, the fullest evidence is necessary ere we can receive it as an undoubted fact. Strictly speaking, the term is only applied to the production of individuals from ova, so as to exclude all cases of gemmation, no body being regarded as an ovum which does not exhibit a *germinal vesicle*, a *germinal spot*, and what is known as *segmentation* of the yelk.

The best known examples that have given rise to this doctrine are the facts observed in the reproduction of *Aphides* (plant lice) and of the *Honey-bee*.

In the case of the Aphides, about autumn, by the union of males and females, true ova are produced. These remain dormant throughout the winter, and in the spring are hatched, but, insead of males and females, the offspring are all hermaphrodite or virgin females. Whatever their true nature, they produce *viviparously* several generations similar to themselves. Towards autumn, however, they produce a final brood, which is made up of males and females, when the same cycle is repeated. The virgin-birth here obviously depends on the question whether the offspring in the first instance are *virgin females*, or, on the other hand, *hermaphrodites*, and this has not as yet been satisfactorily determined.

In the Honey-bee the following are, briefly, the details:—A hive of bees is made up of three classes: (1) *Queen*, or fertile female; (2) *Workers*, or sterile females; (3) *Drones*, or males, only pro-

duced at certain times of the year. These distinct sets all arise from a single individual. At certain periods the queen takes what is known as her *nuptial flight*, accompanied by the males. At this time she becomes impregnated, and whether this occurs *once* in her life or *many times*, she is enabled to produce fertile ova for a *lengthened period*. And now comes the most curious point in these phenomena. The semen of the male is stored up in a special receptacle, which communicates with the oviduct of the queen, but can be shut off at will, and competent observers have found that she apparently allows this semen only to come in contact with the ova that are to produce queens and workers. This is further borne out by the fact that on the occlusion of this oviduct only males are generated. Some authorities, however, assert that, as undoubtedly happens in the case of the queens and workers, where the form of the cell into which the ovum is put, and the food provided for the larvæ, determine to which of these classes the individuals respectively belong, so the production of the males is caused by the physical conditions to which the ova are exposed.

On reviewing the foregoing, one is naturally led to speculate on the resemblance between these phenomena and the so-called alternation of generation. In the case of the bee we have just been describing, we see a course of events by no means unlike what occurs in the Campanularia, if we compare the workers with the trophosome zoöids and the drones with the gonosome.

XIII. *First Law of Quatrefages.*—M. de Quatrefages summarizes the preceding in the following law:—*New individuals may be formed by gemmation from, or division of, the parent being, but this is an exhaustive*

process, and cannot be carried out indefinitely; when, therefore, it is necessary to insure the perpetuation of the species, the contact of the germ and sperm, that is, a true sexual process, is indispensable.

Although sexual reproduction insures the perpetuation of the species, it is very destructive of the life of individuals. It is one of the highest physiological acts the organism is capable of, and is attended by a corresponding strain on the vital energies. This is most strikingly exemplified in the case of insects that die almost immediately after becoming sexually mature.

XIV. *Development* comprehends all the changes that take place in the growth of the ovum to the adult individual.

XV. *Transformation; Metamorphosis.* — These are simply epochs of development, the former usually denoting the change from the ovum to the larval state, the latter the subsequent development to the adult. The last two terms are usually employed solely in studying the life history of those animals whose ova are rapidly hatched, and give rise to very imperfect offspring, owing to incapacity on the part of the parent to provide for their more complete development within her own substance. The fact that such animals, ere they attain to the adult form, go through a series of changes of structure, fitly described as metamorphoses, is sometimes known as the *Second Law of Quatrefages.*

XVI. *Retrograde Development.*—This, strictly speaking, is paradoxical, as development can only be in one direction; it has reference, however, to an apparent degradation in the form of the adult as compared with the embryo. This occurs among certain Crustaceans (Cirrepedia), where the embryo is free swimming and furnished with organs of vision and

sensation, while the adult is more or less deprived of organs of sense, and leads almost a vegetative life; as a compensation, however, it is furnished with reproductive organs, and in this respect at least far more highly developed than the locomotive but sexless embryo.

XVII. *Classification.*—The object of classification is to arrange the various organisms that compose the animal kingdom into groups, according to their more or less likeness to one another. Now, in estimating this, we may regard them from two points of view: we may either be influenced by their apparent, external, or superficial resemblance; or we may judge them by their internal and fundamental structure.

Classifications based on the former plan are known as *artificial*, and although very useful at the period when zoology was in its infancy, are now rightly discarded in favour of those of the latter kind, founded on all the essential and fundamental points of structure, independent of any external similarity of form and habit. These latter are known as natural or philosophic classifications.

The entire animal kingdom is divided into *six primary sub-kingdoms*, based on six distinct plans of structure. The sub-kingdoms in their turn are split up into *classes*, these again into *orders*, orders into *families*, families into *genera*, and genera finally into *species.*

Beginning with the last, species, we may state there are few terms more difficult to define, no two naturalists defining it alike. This difficulty is owing to a curious tendency in nature to stamp upon every organism an individuality of its own. Among the higher grades this is expressed in the

saying that "no two animals are exactly alike." The same may be said to hold good, with modifications, throughout all grades of life, both animal and vegetable. We constantly see individuals born of the same parents differing markedly both from themselves and from their parents, and to these the term *variety* is usually applied; and experiment has shown that by artificially selecting true varieties and breeding from them, in the process of time the descendants so produced will show specific differences from their remote progenitors.

In this way, no doubt, many so-called species have been produced by nature from a common ancestor, and the manner in which this is constantly being brought about and the laws that regulate it have been clearly shown by that eminent naturalist, the late Mr. Charles Darwin, who has most exhaustively treated this subject under the heads of "Survival of the Fittest," and the law of "Natural Selection."

Bearing in mind the foregoing, we may define *species* as *a constant succession of individuals similar to and capable of reproducing each other, and which, as far as human observation goes, do not vary from the general type through more than certain definite limits.*

Genus is a term applied to groups of species that possess essential details of structure in common.

Families are groups of genera agreeing in their general characters.

Orders are groups of families related to one another by common points of structure.

Classes are large divisions comprising animals formed on the same fundamental plan of structure, but differing in the method in which this plan is carried out.

Sub-kingdoms are the primary divisions of the animal kingdom, including all animals which are formed on the same structural type, irrespective of the specialization of function they possess.

In the systematic portion of these papers it will be found later on we have placed the Annulosa before the Mollusca; we have done this because, with respect to movement and sensation, especially animal functions, the former are much in advance of the latter, although the latter excel them in their vegetable functions, that is, in digestion and secretion; they are also constructed on a somewhat higher type, so that on the whole it is a doubtful question as to which should stand first.

XVIII. *Geographical Distribution.*—As we have seen, the maintenance of life depends largely on the external surroundings of the animal being of a favourable character, so we should expect the vitality of a species to be more vigorous in proportion to the accuracy of the balance maintained between the economy of the organisms composing it, and the surrounding physical conditions. As these latter are found to vary greatly in different parts of the world, we are not surprised to find that in most cases the area of the distribution of a species is more or less sharply defined, although there are at the same time a considerable number of species to which the term *cosmopolitan* is given, denoting the wide-spread character of their distribution.

XIX. *Vertical or Bathymetrical Distribution.*—This relates to the depth within which each marine species is confined. As a rule, each has a definite bathymetrical zone in which it is always found, and out of which its existence is difficult, if not impossible.

There are four generally accepted zones characterized by possessing a special fauna of their own.

(i.) *Littoral Zone.*—This is the tract between tidemarks.

(ii.) *Laminarian Zone.*—From low water to 15 fathoms.

(iii.) *Coralline Zone.*—From 15 to 50 fathoms.

(iv.) *Deep Sea Coralline Zone.*—From 50 to 100 fathoms and more.

Recent researches have shown that there are organisms that flourish at a considerably greater depth than this, and another zone has been suggested going down to 2,500 fathoms and more; in this last zone the distribution of animals seems to be influenced more by the *temperature* than the *depth* of the water.

XX. *Distribution in Time.*—Many interesting and important facts are constantly being discovered in this direction, but only a few remarks are called for here.

The crust of the earth is made up of two kinds of rocks. (1.) *Igneous*, produced by the action of heat, which are unstratified. (2.) *Stratified*, produced by the action of water, being deposited in more or less distinct layers or strata.

In the former no fossils have ever been discovered, while the latter are rich in such remains.

All known fossils can be readily referred to one of the primary sub-kingdoms of the animal world, although they differ more or less from present forms in proportion to the age of the strata in which they are found.

Most fossils are representatives of species now

extinct, and a species, when once it has become extinct, never re-appears.

The oldest known fossil is called the *Eozöon Canadense*, and is found in the oldest stratified rocks, the Laurentian. It is usually regarded as a gigantic Foraminifer.

The stratified rocks are divided into:—(1.) *Palæozoic*, or primary. (2.) *Mesozoic*, or secondary. (3.) *Kainozoic*, or tertiary.

The fossils found in the *Palæozoic*, or ancient-life period (πάλαιος, ancient; ζοον, life), are characterized by their marked divergence from all existing forms of life.

Those of the *Mesozoic*, or middle-life period (μέσος, middle), although for the most part very different, still show a tendency to approximate more nearly to the character of existing forms.

In those of the *Kainozoic*, or new-life period (καινὸς, new), the fossils approximate still more nearly, and many are specifically identical with recent species.

XXI. *Origin of Species* (*Darwinian Theory*).—According to this, *all* the multiple forms of animal and vegetable life are derived from a *few* "primordial" types, the descendants of whom have been acted upon during vast epochs of time by various natural laws, giving rise to numberless variations.

This theory is based on the following fundamental propositions:—

(i.) In *every* species individuals *tend to vary* from the parent type in some particular or other, and these variations can be transmitted to future generations under certain definite and discoverable laws of inheritance.

(ii.) By *artificially* breeding from individuals possessing variations from the parent stock, man has been enabled to produce breeds in which these variations were *permanent*, or, in other words, to give rise to *new species*.

(iii.) The world in which all life is placed is *constantly varying* in its *physical conditions*, and has been subject to still more mighty changes in the past, and as all life tends to adapt itself to its surrounding physical conditions, for otherwise it would die out, innumerable variations must have arisen in living organisms in their "*Struggle for Existence.*"

(iv.) All animals and plants produce more offspring than can, by any possibility, be preserved, and as none of these are exactly alike, a "*Natural Selection*" will take place, in which there will be a "*Survival of the Fittest.*" Those individuals possessing variations *favourable* to the conditions of life under which they chance to be placed *will survive* and transmit these advantages to their offspring, who, in their turn, will be subject to the same laws. On the other hand, those individuals which *do not* possess favourable variations will be placed at a disadvantage in the "Struggle for existence," and tend to die out. By a repetition of this process "*varieties*" are first established, and, finally, after a lapse of great time, the differences become so marked as to constitute *species*.

At the present time the doctrine that each species is an immutable creation, and has always been so, is held by few, while the Darwinian Theory, which,

as we have seen, derives all existing forms of life from extinct progenitors that flourished at far remote periods of time, by a process of evolution, is more or less generally received. The upholders of the former doctrine have shifted their ground; instead of maintaining, as hitherto, that *all* species were specially created, they now allow the working of the laws of evolution in the production of a *large number* of species from earlier forms, but insist that these latter were the result of special creation. When once, however, the thin end of the wedge is admitted, who can tell what will follow? Having conceded this first point, where will the believers in special creation be able logically to draw the line? If they admit that some species have been formed by variation, how will they be able to distinguish between created forms and those originating from secondary laws?

In the following trenchant questions Mr. Darwin has ably shown the difficulty of his opponents. "Do they," says he, "really believe that at innumerable periods of the earth's history certain elemental atoms have been commanded suddenly to flash into living tissues? Do they believe at each supposed act of creation *one* individual or *many* were produced? Were all the infinitely numerous kinds of animals and plants created as *eggs* or *seeds*, or as *full grown*; and, in the case of mammals, were they created, bearing the *false* marks of nourishment from the mother's womb?"

That many of Mr. Darwin's conclusions are as true and undoubted as any so-called natural law with which we are acquainted few will venture to deny. The controversy of the present and of the future for those who interest themselves in such specula-

tions, will be as to the origin of the "primordial" type or types from which have been generated the multitudinous forms of life, both animal and vegetable, now inhabiting the world; were they specially created, or were they formed from the earth spontaneously (*αυτοχθονες*), as the ancients believed, the product of matter under certain conditions acted upon by chemical and physical laws? May vital energy itself be but a "marvellous correlation" of ordinary physical forces?

Mr. Darwin would seem to incline to the former view. In the "Origin of Species" he says:—"Therefore I should infer from analogy that probably all the organic beings which have ever lived on this earth have descended from some one primordial form into which life was first *breathed by the Creator*."

On the other hand, the materialist may urge that it is as difficult to understand *one* special creation as a *thousand*; he may point to the heterogenist theory of spontaneous generation, which can hardly be said to have been disproved, and say, "Have we not constantly before our eyes instances of inert matter becoming metamorphosed into life?"

Professor Tyndall, too, would seem to lend the weight of his authority to this view. In the celebrated Belfast address he thus sums up the respective merits of the two questions:—

"Two courses, and two only, are possible. Either let us open our doors freely to the conception of creative acts, or, abandoning them, let us radically change our notions of matter. Let us reverently but honestly look the question in the face. Divorced from matter where is life to be found? Whatever one's faith may say, our knowledge shows them to be indissolubly joined—every meal we eat, and every cup we drink, illustrates the mysterious control of

mind by matter." Again, further on, he says :—" By an intellectual necessity I discern in that matter which we in our ignorance of its latent powers, and notwithstanding our professed reverence for its Creator, have hitherto covered with opprobrium, the promise and potency of all terrestrial life."

XXII. *Spontaneous Generation.*—By this is understood the production of living beings without the pre-existence of germs, and, therefore, also without the pre-existence of parent organisms.

It is a question that at the present time is anything but definitely settled, and the following are the phenomena on which the belief is generally based :—

If an animal or vegetable substance be treated with cold or hot water, so as to form an organic solution, and this be exposed to the air for a sufficient time, a series of changes are observed to take place.

(i.) There forms on the surface a thin scum or pellicle, which is found to be made up microscopically of a vast number of minute granules.

(ii.) In the next stage the granules appear to run together in twos and threes, to form short filaments called Bacteria, which become longer by uniting with one another, and by the addition of other granules to their extremities; they are then termed Vibrios, and both Bacteria and Vibrios now manifest vibratile or serpentine movements. After a time the Bacteria and Vibrios become motionless and undergo degeneration, and, again, a finely-granular pellicle is produced.

(iii.) We next observe that this pellicle, at first uniform, changes in appearance here and there, owing to a concentration of the granules into more

densely-aggregated spherical masses, which at last become limited by a more or less clear border, resembling the *zona pellucida* of the egg of higher animals. The next change observable is, that the granules that had been at first more densely aggregated towards the centre now disseminate themselves uniformly through the ovum, whilst, at the same time, the clear *zone* thickens into a distinct membrane; a short time after this, differentiation still proceeding, the mass of inclosed granules gradually become converted into a real embryo, which manifests its existence by slow movements, "at first by simple oscillations in the mass of granules, and then by regular uniform movements of revolution of the whole contents within its enveloping membrane. Then, after a time, a pale spot appears in a certain part among the granules, and soon the alternate contraction and dilation of this show that it is the rudiment of the future heart, or contractile space of the Infusorial animalcule. As other parts become differentiated and the proper structure of the animal is attained, it begins to exhibit movements of quite another kind—sudden and irregular—no longer checked by slight shocks from without. In one of these sudden plunges the enveloping membrane is ruptured, and there enters upon the world of waters a free, swimming, and perfectly formed Infusorial animalcule, the offspring of Death and the embodiment of Life."

The Panspermists endeavour to explain the foregoing by alleging that the atmosphere is full of *innumerable germs*, too minute to be visible to the most powerful microscope; that *these are deposited* in all putrefying matters, finding there a suitable *nidus* for their development, and that, if this atmospheric air be excluded, or deprived of its germs by

being made to traverse certain purifying agencies, the above phenomena do not take place.

Dr. Bastian, on the other hand, has declared "That certain organisms which have been shown to be destroyed by a temperature of 100° C., may be obtained in organic fluids, either acid or alkaline; which, whilst enclosed in hermetically sealed and airless flasks, had been submitted to not only such a temperature, but even to one varying between 146° C. and 154° C. for four hours."

At the meeting of the British Medical Association, in 1870, Professor Huxley gave an opinion adverse to the theory of Heterogeny, saying that he considered there were probabilities of error in Dr. Bastian's experiments; and, doubtless, the views of so eminent an authority are worthy of the greatest weight. At the same time, their value was not heightened by the learned professor displaying a certain amount of bias on the question, observing that he *preferred* the conclusion that living matter could resist extremes of temperature to the other hypothesis of Spontaneous Generation.

To students, the question whether the vitality of any germ can or cannot resist a temperature of 146°-153° C. is of more importance than the favourite theory of any scientist, however celebrated, and until conclusively answered in the affirmative, the believers in the accuracy of Dr. Bastian's experiments will justly consider themselves entitled to be placed at least on the same footing as their opponents.

Not a few favourers of Heterogeny, while they are disposed to allow the possible material evolution of the Bacteria, Vibrios, and kindred organisms of the lowest kind, reject that doctrine in the case of the more highly-organized Infusorians that make

their appearance in the latter stage of putrefying solutions, considering that any specialization of function, some degree of which these unquestionably possess, pre-supposes a struggle for existence through many generations. "In medio tutissimus ibis"—probably the truth lies somewhere between the conflicting parties.

As these papers are specially meant for the use of students of medicine, a few words on certain subjects that belong to that department of science, but which are believed by many to be intimately connected with the genesis and development of certain lowly organisms, may not be inappropriate.

XXIII. *Germ Theory of Disease.*—At the present day there is a growing tendency among pathologists to ascribe many diseases to the development of living germs in the blood or fluids of the animal body. The way in which these gain entrance is doubtful, but it is probably either through the lungs, stomach, or skin; having once entered in, however, they develop at the expense of the animal, living on certain constituents that do not appear to be invariably present, and where this "materies morbi" is absent it is thought there is no susceptibility to the disease. These germs are necessarily very minute, and invisible to the most powerful microscope, but nevertheless the observed history of many diseases furnishes a strong *à priori* presumption in favour of their existence. Let us take, for instance, the exanthemata, or zymotic diseases. In the first place, we observe that they are very contagious, which we may explain by supposing that large numbers of similar germs are constantly being reproduced, and scattered abroad by the infected individual. We next observe that they have a period of incubation,

or time during which the germs may be undergoing development; and, finally, they run a definite course, reaching a maximum, then gradually declining, and, at length, disappearing. Here, again, a living organism is strongly suggested, for we should expect such, having attained maturity, to gradually die out, as the pabulum through which it grew became consumed. We should expect also, as experience shows to be the case, that any having once suffered from this kind of disease would not readily be again infected by the same; for, as we have already premised, this pabulum is not considered to be a normal and necessary constituent of the blood, or animal fluids, but one of accidental occurrence, and, although generally present, differing considerably in degree in different individuals, and by no means unfrequently absent altogether; and when once it has been eliminated, it by no means necessarily reappears, and when it does so, only after the lapse of years, and in nothing like its former abundance.

Dr. Sansom thus enunciates this theory in his "Antiseptic Systems." "The poisons of spreading diseases," says he, "are extremely minute living organisms, having the characteristic endowments of vegetable growths, analogous to the minute particles of vegetable protoplasm, whose function it is to disintegrate and convert complex organic products, owing their specific properties in the special diseases, not to any botanical peculiarities, but to the characters implanted into them by the soil in which they first sprang from innocuous parents, and from which they are transmitted, this soil (except in the case of their earliest origin) being the fluids of the animal body."

The circle of diseases in which germs are supposed to play an important part seems to be

widening year by year. A short time ago Mr. Hutchinson gave strong reason for classing syphilis with the exanthemata; and only just recently Professor Koch, by some elaborate and valuable experiments, has shown that it is extremely probable that certain Bacteria, which he has been enabled to isolate, have an intimate relation with the development of tubercular phthisis.

Nor is this Bacterion of Koch the only disease germ that has been definitely isolated, and rendered visible to us by the microscope; competent observers believe they have identified a minute fungus as the cause of malarial fever, and certain micrococci as standing in the same relation to typhoid fever. Several more instances might be given, and their number increases yearly.

XXIV. *Antiseptic System; Listerism.*—This is a natural outcome of the germ theory. No sooner was the latter definitely enunciated, than at once this important question was debated by physicians: If the animal economy is liable to the direct attacks of certain low forms of life, is it not feasible that there may be certain agents by whose destructive action on such organisms protection might be afforded to the exposed animal?

Phenol or carbolic acid was found to be peculiarly deadly to all such, an infinitesimal quantity being sufficient to destroy instantly Bacteria, Vibrios, Amœbæ, Monads, Rotiferæ, and Vorticellæ, and to accomplish this without any obvious chemical action. Observing, therefore, the destructive power of carbolic acid in the case of germs that could be seen, it was justly argued that this agent might have a similar potency over the unseen; and influenced by this reasoning, for some time past, many eminent

physicians and surgeons have sought to treat germ diseases by attempting to avail themselves of this peculiar property of carbolic acid, though up to the present time with but limited success.

Professor Lister was one of the leaders of the movement. This well-known surgeon, assuming that erysipelas, septicæmia, and the various poisons originating in the putrefaction of wounds, were directly due to the presence of atmospheric germs, resolved to avail himself of the observed properties of carbolic acid, and to do this he determined to place before every wound a protective layer of the same, which all germs should be compelled to traverse before gaining entrance to it, considering that in this way they would necessarily be destroyed and lose all their potency for evil.

The following was the procedure he advocated :— As soon as possible after the wound was received, it was to be injected and washed out thoroughly with a solution of carbolic acid ; the skin in its vicinity was next cleansed with the same, and a spray, also containing a percentage of carbolic acid, was brought to bear on the part ; under cover of this, various textures saturated with the same agent were closely applied over the wound and the adjoining parts for a considerable distance round ; this protective covering was to be retained throughout the whole of the repair of the part, and the wound never to be uncovered except under the protection of the spray, nor was it to be touched either with finger or any instrument unless first dipped in a solution of carbolic acid. Neglect of any one of these precautions was calculated to vitiate the whole.

Following these principles, Mr. Lister has met with results which, to say the least, have never been surpassed by any other surgical process. That the

atmosphere does contain germs has been placed beyond doubt by many observers, for they have been isolated and examined microscopically on many occasions; it is also certain they vary in number in different situations; for instance, it has been shown they are extremely few in number, if not absent altogether, at any considerable altitude. It is worthy of note that in such situations, also, putrefaction does not occur with anything like the same facility, and that wounds also undergo a much quicker reparative process, and have considerably less tendency to suppuration.

It cannot be denied that these observed facts tell strongly in favour of Listerism; on the other hand, opponents, while admitting the occasional presence of germs in the atmosphere, deny that they are numerous enough to have that potency for evil the Listerians assert, and at the same time quote the statistics of other surgeons, showing that exceedingly good results are not limited to Listerism, but that other methods, provided the same amount of care and attention is bestowed, yield equally good results.

Vaccination.—This most important practice is based on experience derived from the history of zymotic disease from the germ theorist's point of view. Universal experience has taught us that sufferers from any kind of zymotic disease seldom have a repetition of the same at any subsequent period of their life; if by chance they do, its virulence is of the most trifling character. We have lately shown how this is susceptible of explanation by means of the germ theory of disease.

Now, it is well known that many organisms, differing considerably in their character, are capable of thriving on the same pabulum, and Mr. Darwin has shown

how, among the higher forms of life, if two unlike species are located together, capable of thriving on the same food, the more vigorous, by exhausting this, will cause the other to die out, and if the food be limited, will itself eventually succumb ; so experience has taught us that by inoculating an individual with a mild disease, we may take away from his system the *materies morbi* of a more serious one, or, to use the germ theory nomenclature, by giving voluntary entrance into the blood to a harmless organism, we effectively close the same channel against a far more deadly one, by allowing the former to consume all the pabulum that alone is capable of supporting the life of the other.

As with vaccine lymph we inoculate our patient, we put into his blood the vaccinial germ, and we then watch the subsequent development and decay of the vaccinial organism. If, then, we were to inoculate the same individual with the variolous germ, we should find that in all probability no symptoms followed, the latter having lost all means of developing. We have frequent experience of the converse of this, and sometimes, moreover, we are able to observe the action of the two germs when they have more or less simultaneously gained an entrance into the blood. The phenomena that then follow are beautifully suggestive of the foregoing conclusions, for we find that, if infection occur at the same time, the development of the vaccinial organism being the quicker, it is enabled to overcome the variolous organism in the struggle for existence, and to appropriate for its own benefit most of the common pabulum present in the blood, and in this way it renders the development of the latter abortive ; on the other hand, if the variolous injection take place at some little time prior to that of the other, the contrary result is observed : the variolous

organism, having the start, is enabled to develop first and to flourish at the expense of the latter. Recent experiments on the Continent by the eminent Pasteur have rendered it not unlikely that analogous processes may ere long be introduced to mitigate the virulence of other germ diseases.

SECTION II.

The animal world is divided into two large kingdoms, known as the VERTEBRATA and INVERTEBRATA, on the characteristic distinctions between which we shall say a few words later on.

Commencing with the INVERTEBRATA, the following are their sub-kingdoms :—

I. *Protozoa*	
II. *Cœlenterata*	
III. *Mollusca*	INVERTEBRATA.
IV. *Annuloida*	
V. *Annulosa*	

I. PROTOZOA (πρῶτον, first; ζόον, animal).—These, as their name implies, are the most lowly organized of the animal world, and hence it is difficult, if not impossible, to give an exhaustive definition of them. The following, however, defines their most important characteristics :—

The *Protozoa* are animals generally of *minute size*, composed of a *nearly structureless jelly-like substance* (sarcode), showing no composition out of definite parts or segments, having *no definite body cavity*, presenting no traces of a nervous system, and with no differentiated alimentary apparatus, or a *very rudimentary one*.

The *Protozoa* are almost always *aquatic*. They may sometimes form colonies of considerable size.

The only traces of a vascular system that they furnish are certain clear spaces called "*contractile vesicles*," which are found in some species, and probably perform the functions of a heart.

In the higher *Protozoa* a distinct alimentary aperture is present, and rudimentary organs of generation sometimes exist; but in the great majority of this sub-kingdom a true sexual process has not been made out.

Active locomotion is enjoyed by many *Protozoa;* in some cases it is very limited, so that in adult life the animal becomes permanently fixed.

The apparatus by which locomotion is attained is of varied character; in the higher members it is by means of *small hair-like processes*, termed *cilia*, which have the power of vibrating very rapidly, or these may be replaced by *long whip-like bristles*, known as *flagella*, which act in a similar manner; but the most characteristic organs of locomotion among the lower members are *pseudo-podia* or *false feet* (ψεῦδος, false; πούς, foot). These are little processes of sarcode that can be emitted from the general substance of the body and retracted at the will of the animal, being completely fused with the body substance.

The following is a tabular view of the divisions of the PROTOZOA:—

Class I.	GREGARINIDÆ.	Class III.	INFUSORIA.
Class II.	RHIZOPODA.	Order (1)	*Suctoria.*
Order (1)	*Amœbea.*	(2)	*Ciliata.*
(2)	*Foraminifera.*	(3)	*Flagellata.*
(3)	*Radiolaria.*		
(4)	*Spongida.*		

Class I. GREGARINIDÆ. — These are *Protozoa*, *destitute of a mouth* and *without the power* of emitting pseudo-podia. They are usually found in the

alimentary canal of certain insects, and their degraded condition is not improbably due in some measure to the fact that they are internal parasites, and as such not dependent on their own exertions for food.

Structure.—Anatomically, the structure of a Gregarina is very simple; it resembles an unimpregnated ovum. An adult Gregarina may be regarded as a single cell, consisting of an ill-defined membranous envelope, filled with more or less granular sarcode with fatty particles. It contains in its interior a vesicular nucleus, this in turn inclosing a solid particle or nucleolus.

In magnitude the Gregarinæ vary from the size of the head of a small pin, up to as much as half an inch in length, when they look like small worms. The integument with which the sarcode body is covered may be quite smooth or striated, or it may be furnished with bristles or spines, or in some cases with cilia; sometimes one end of the body is provided with uncinate processes, very similar in appearance to the hooked head of the common tape-worm.

Digestion.—No differentiated organs of any kind beyond the *nucleus* and *nucleolus* have been found, and both assimilation and growth must be performed simply by the *general surface of the body.*

Locomotion.—Slow movements may sometimes be effected by contraction of the body, but not by pseudo-podia.

Reproduction.—The following interesting phenomena have been observed with respect to the reproduction of the Gregarinidæ:—

A Gregarina—or two individuals which have come

together and adhered—assumes a globular form, becomes motionless, and develops round itself a structureless envelope or cyst; the central nucleus then disappears, apparently by dissolution, whereupon the granular contents of the cell break up into little rounded masses which gradually elongate and become lanceolate, when they are termed "*pseudo-naviculæ;*" the next step in the process is the liberation of the *pseudo-naviculæ*, which escape by the rupture of the inclosing cyst. If they now find a suitable medium they give rise to little sarcodic masses, which exhibit lively movements, and are endowed with the power of throwing out and retracting little processes of the body resembling the pseudo-podia of the Rhizopoda. Finally these bodies are developed into adult Gregarinæ. It will be seen that the formation of the *pseudo-naviculæ* out of the granular contents of the body, subsequent to the disappearance of the nucleus, presents some analogy to the segmentation of the impregnated ovum, which follows upon the dissolution of the germinal vesicle.

Class II. Rhizopoda.—These are *Protozoa*, destitute of a mouth, which may be simple or compound, and *possess the power of emitting pseudo-podia.* From the last characteristic the name of the class is derived (*ρίζα*, root; *πούς*, foot).

Structure.—A typical Rhizopod is but a simple mass of sarcode, with no more differentiation than a Gregarina, but possessing the power of *emitting and retracting at will* small processes known as *pseudo podia* from the general surface of its body. These *pseudo-podia*, or false feet, are merely filaments of sarcode and somewhat analogous to the little processes at times observed in white blood corpuscles and pus cells, and Professor Huxley has remarked

that an amœba is structurally "a mere colourless corpuscle leading an independent life."

The RHIZOPODA are divided into four orders:—

(i.) *Amœbea*, (ii.) *Foraminifera*, (iii.) *Radiolaria*, (iv.) *Spongida.*

Order (i.) *Amœbea* are Rhizopods that usually *are naked*, and are furnished *with short blunt pseudo-podia* that *do not anastomoze.* They also contain a *nucleus* and *one or more contractile vesicles.*

Structure (taking Amœba as a type).—This animalcule is composed of gelatinous sarcode that can be separated into two layers—an inner and an outer (endosarc, ectosarc); the latter is highly contractile and is the layer out of which the pseudo-podia are chiefly composed, while in the inner or endosarc are found the nucleus, the contractile cavities, and certain fortuitous cavities known as "food-vacuoles." A few members of this order (Arcellinæ) are protected by a membranous envelope, strengthened by grains of sand and other solid particles, known as a "carapace."

Digestion and Absorption.—As in Gregarinidæ.

Circulation.—In the endosarc are found small cavities, usually only one to each individual, though sometimes more, which undergo a periodic contraction (systole) and dilation (diastole). Some observers have stated that during systole tubes have been seen *radiating from these cavities.* Whether this be true or not, probably we have here the *earliest and most rudimentary form of a vascular system.*

Nervous System.—No trace.

Locomotion is effected irregularly, but with some activity, by means of pseudo-podia.

Reproduction.—A true sexual process is unknown; but reproduction may take place in three ways:—

(i.) Simple fission, an animal dividing into two parts, each becoming an independent organism.

(ii.) By detachment of a single pseudo-podium.

(iii.) By production of little masses of sarcode, possibly derived from the nucleus, or by a segmentation of the endosarc, the animal having become previously torpid, the nucleus and contractile vesicle at the same time disappearing; these little masses, when liberated, develop into adult individuals. This process is evidently analogous to the formation of the pseudo-naviculæ in the Gregarinæ.

Order II. *Foraminifera.*—These may be defined as Rhizopods, *provided with a shell or test* usually composed of carbonate of lime. Their pseudo-podia are *long and filamentous*, and often form a *network* by interlacing.

Structure.—Body is composed of contractile sarcode, usually red or yellowish in colour; it is not divisible into ectosarc and endosarc, and both nucleus and contractile vesicle are absent. Nearly always a shell or test is present, but this is not a true cuticular secretion like that of Mollusca, for the sarcode not only fills the interior, but forms a thin film on the exterior, from which the pseudo-podia are emitted; hence the shell is immersed in the sarcode.

From the curious interlacement of the pseudo-podia this order has been known by the name Reticulosa (*rete*, net).

Circulation.—None.

Digestion and Absorption.—As in Rhizopoda.

Distribution of the Foraminifera in Time.—This order is very ancient; it is found in the Palæozoic, Mesozoic, and Kainozoic formations. The oldest known fossil, the Eozoon Canadense, is considered to be the remains of a gigantic Foraminifer.

Order III. *Radiolaria.*—This order, which was formed to include a few species, chiefly on account of the form of the pseudo-podia, is composed of Rhizopods, possessing a *siliceous test*, or *siliceous spicules*, and having pseudo-podia that *stand out like radiating filaments.*

With regard to their internal structure and physiology, our remarks with regard to the order Foraminifera will apply equally to these.

Order IV. *Spongida.*—Sponges were long regarded as being vegetable in origin, but are now universally referred to the animal world, and considered to stand in or near the Rhizopoda. They may be defined as *sarcode bodies destitute of a mouth*, united into a composite mass which is traversed by *canals opening on the surface*, and is almost always supported by a *framework of horny fibres*, or by *siliceous or calcareous spicules.*

Structure (taking Spongilla, or common freshwater sponge, as example) consists essentially of two parts: a gelatinous investing flesh and an internal framework or skeleton. The latter is composed of horny, reticulated fibres interlacing in every direction, and pierced by numerous apertures, the whole covered internally and externally by a gelatinous substance (sponge flesh) somewhat resembling white of egg. Of the apertures that penetrate the substance of the sponge in every direction, the larger are called *oscules*, or *exhalant apertures*; the smaller, *pores*, or *inhalant apertures.*

The sponge flesh is found to be made up microscopically of an aggregation of amœbiform bodies, known as sponge-particles or sarcoids ; some of these are ciliated, while others are capable of emitting pseudo-podia from any part of their body surface, possess nuclei, and altogether resemble Amœbæ ; so that, broadly speaking, a sponge may be considered to resemble a colony of Amœbæ with a skeleton superadded.

Circulation and Digestion.—A constant circulation is kept up in a living sponge by means of a water vascular system. The water passes in through the inhalant apertures, or pores, and is conveyed by canals (afferent) to a second series of tubes (efferent), by which it reaches the oscules and is finally expelled.

The mechanism by means of which these processes are performed is very interesting: beneath the superficial layer of the sponge there are chambers lined with sponge-particles with vibratile filaments or cilia ; the pores open into these chambers, and the incurrent canals have also their commencement here, each being dilated for a little way, and also lined with ciliated sponge-particles.

By these cilia currents of water are caused to set in through the pores and go out by the oscules, and in this way fresh water circulates through the entire sponge.

Reproduction.—In two ways, either asexually or sexually.

(i.) *Asexually.*—In winter the deeper portions of the sponge become filled with small seed-like bodies, termed *gemmules* or *spores ;* these in the spring become capable of reproducing the adult sponges.

(ii.) *Sexually.*—Certain sponge particles or sarcoids, having separated themselves, become nucleolo-nucleated, like ova; simultaneously with this certain sarcoids become motionless, and their contents, first becoming granular, are afterwards converted into spermatozoa. When these become ruptured, the latter are liberated, and contact of the different elements is produced, with a resulting embryo, at first ciliated and moving about freely, but after a time becoming fixed and developing into a new individual.

Distribution of Sponges in Space.—Nearly all are exclusively marine; the Spongillæ alone are inhabitants of fresh-water.

Distribution in Time.—Remains of sponges are found in Palæozoic, Mesozoic, and Kainozoic formations, the order on the whole attaining its maximum in the Cretaceous epoch.

Class III. Infusoria.—These are *Protozoa* that are usually provided with a mouth and rudimentary digestive cavity. They do not possess the power of emitting pseudo-podia, but are furnished with vibratile cilia. They are very minute, usually microscopic in size, and their body is divisible into three layers. Their name is derived from the fact that many of the animalculæ that appear in organic *infusions* during decomposition belong to this class.

Structure (taking Paramœcium as a type).—The body is bounded by a structureless transparent pellicle, the "cuticle;" this is lined by a layer of firm, consistent sarcode, termed the cortical layer, or "parenchyma of body." Lastly, there is a central mass of more diffluent sarcode, the chyme mass or abdominal cavity.

Vibratile cilia cover the cuticle, which is perforated

by the aperture of the mouth, leading into a funnel-shaped gullet lost in the chyme mass. Within the cortical layer are situated the nucleus, nucleolus, and contractile vesicle or vesicles—seldom more than one. There is a distinct anal aperture near the mouth ; certain spaces, termed "vacuoles," are also sometimes present.

Digestion and Respiration.—Chiefly through the currents of water set up by the vibrating cilia, which are constantly bringing nutritive particles through the mouth into the central abdominal cavity.

Nervous System.—No trace.

Locomotion.—By means of cilia.

Reproduction.—Either (1) asexually by fission, or (2) by a true sexual process. The two Paramæcia come together by their ventral surfaces. The nucleus, which here seems to resemble an ovary, gives rise to a number of ovules in its interior ; likewise in the nucleolus of each, which we may compare to a testis, are formed a number of rod-like bodies believed to be spermatozoa. The nucleus of each next passes by the mouth into the body of the other, and contact of the two reproductive elements takes place, whence are formed a number of germs, each capable of reproducing an adult Paramœcium.

It is noteworthy that to this order belongs the *Noctiluca*, to which animalcule the phosphorescence of the sea is mainly due.

The Infusoria are usually divided into three orders—(1) *Ciliata*, (2) *Suctoria*, (3) *Flagellata.*

(1) *Ciliata* include those Infusorians that are abundantly furnished with cilia, either for locomo-

tion or for procuring food, hence the name of the order. Paramœcium and Vorticella are types of this order.

(2) *Suctoria.*—This order, of which *Acineta* may be taken as a type, is rather anomalous; its members are mostly furnished with a number of filamentous tubes having at their extremities suctorial discs, which serve both for the ingestion of food, and also for seizing their prey.

(3) *Flagellata.*—These are Infusorians with long flexible filaments known as "Flagella," which are used chiefly for the purpose of locomotion; cilia are sometimes present also. *Peridinium* may be taken as a type of this order.

Affinities of the Infusoria.—The position of the Infusoria cannot be regarded as absolutely settled. Many competent naturalists think they should be placed considerably higher than the *Protozoa*, and be ranked near the *Annuloida.*

II. Cœlenterata (κοιλὸς, hollow; εντερον, entrail).—This sub-kingdom derives its name from its members being distinguished by the possession of a *distinct somatic* or *body cavity*, and includes most of the animals formerly included in Cuvier's *Radiata.*

They may be defined as animals whose alimentary canal communicates more or less freely with the general cavity of the body: their body substance is composed of *two fundamental membranes*, an inner "endoderm" and an outer "ectoderm." They present *no distinct hæmal or neural regions*, and usually there are *no traces of a nervous system.* Many of them possess peculiar stinging organs or thread-cells, and generally a radiate condition of the organs

is noticeable, especially in the tentacles with which most are provided. In all, *distinct organs of reproduction* have been shown to exist.

Comparing this sub-kingdom with the last, we find a distinct advance in the specialization of the digestive function; we meet with a condition transitional between the simple digestion of the Protozoa by mere body surface absorption, and the digestion of animals above the Cœlenterate class, in which there is usually an alimentary tract entirely shut off from the general somatic cavity: for, here are suggestions of the more elaborate condition; in the Hydrozoa, what we may call the stomach of the animal, and the body cavity, correspond, but we find in the Actinozoa, although the two communicate freely, a distinct attempt at differentiation.

The following is a tabular view of the divisions of the Cœlenterata:—

Class I.		HYDROZOA.	
Sub-Class	(i.)	*Hydroida.*	*Examples.*
Order	(1)	*Hydrida*	(Fresh-water Polype).
	(2)	*Corynida*	(Coryne).
	(3)	*Sertularida*	(Sea-firs).
	(4)	*Campanularida.*	
Sub-Class	(ii.)	*Syphonophora.*	
Order	(1)	*Calycophoridæ.*	
	(2)	*Physophoridæ*	(Portuguese man-of-war).
Sub-Class	(iii.)	*Discophora.*	
Order	(1)	*Medusidæ*	(Jelly-fish).
Sub-Class	(iv.)	*Lucernarida.*	
Order	(1)	*Lucernariadæ.*	
	(2)	*Pelagidæ.*	
	(3)	*Rhizostomidæ.*	
Sub-Class	(v.)	*Graptolidæ*	(extinct).

Class II.	ACTINOZOA.	*Examples.*
Order	(1) **Zoantheria*	(Sea-anemone).
	(2) **Alcyonaria.*	
	(3) *Rugosa* (extinct).	
	(4) †*Ctenophora.*	

Hydrozoa.—These are Cœlenterata in which there is no attempt at separation between the walls of the digestive sac and the general body cavity, the two communicating with one another. The organs of reproduction appear as external processes of the body wall.

Structure.—The body of a Hydrozoon, on transverse section, appears as a *single tube*, the walls of which are formed by the limits of the combined digestive and body cavity. As we have before seen, in the general definition of the sub-kingdom, it is composed of two primary membranes or fundamental tissues, the ectoderm and endoderm, the former of which gives rise to the outer surface of the body, while the latter lines the alimentary canal, the general cavity of the body, and the tubular tentacles. These membranes are the representatives of the primitive serous and mucous layers of the germinal area, and become differentiated in opposite directions, the ectoderm growing from within outwards, and the endoderm from without inwards.

Circulation.—There are no traces of a vascular system.

Nervous System.—No traces.

Digestion.—By absorption of nutrient matters in the alimentary canal and body cavity.

* Both coral-producing and fixed Zoophytes.
† Free swimming.

Reproduction.—Sometimes asexually by gemmation, but at others, in the same animal, by a true sexual process. Ova and spermatozoa are produced in external processes of the body; when mature the ovum is expelled through the body wall, and is fecundated by the spermatozoa that are liberated at the same time. The embryo appears as a minute, free-swimming, ciliated body.

In some *Hydrozoa* (Corynida) phenomena both curious and interesting occur, in connection with their reproduction, deserving of some brief notice. The reproductive elements are developed in distinct sacs, which have been aptly called "gonophores" by Professor Allman, and which appear as external processes of the body wall: these generative buds vary greatly in their form and development; in some species of *Coryne* they exist in their simplest form, namely, as *protuberances of the endoderm and ectoderm inclosing a portion of the somatic cavity.* In this form they are termed "sporosacs," and are exactly like the buds previously spoken about, with this difference, that they are not themselves developed into fresh organisms, but are simply receptacles in which the essential elements of generation—the ova and spermatozoa—are prepared.

Among the *Cordylophora* a further advance is observable: the gonophore here consists of a closed sac, from the roof of which depends a hollow process—the "manubrium"—from which are given off a system of tubes running in the walls of the sac; the gonophore in this case is said to have a "disguised" medusoid structure.

A still higher form of structure, however, is met with in certain Corynida, where the gonophores are said to be "medusoid." In these cases, the genera-

tive bud is at first simply a sporosac, but, later on, develops into a much more complicated structure: the gonophore is seen to be made up of a bell-shaped disc termed the "gonocalyx," attached by its base to the parent organism, and having its cavity turned outwards. From the roof of the gonocalyx there hangs down a peduncle, or "manubrium," containing a process of the somatic cavity: the manubrium gives out at its fixed end four prolongations of its cavity in the form of radiating lateral tubes, which run to the margin of the bell, where they communicate with one another by means of a single circular canal, surrounding the mouth of the bell. This system of tubes is known as the system of the "gonocalycine canals." The gonophore in this state may remain attached to the parent organism, but, in other cases, further changes ensue. In the higher forms of development the manubrium acquires a mouth at its free extremity, and the gonocalyx becomes detached from its parent. The gonophore now behaves as an independent organism. The gonocalyx is provided with marginal tentacles, and with an inward prolongation from its margin, which partially closes the mouth of the bell, and is termed the "velum." By the contractions of the gonocalyx, which serves as a swimming organ, the gonophore is propelled through the water. The manubrium, having now the shape, assumes the functions of a polypite, and its cavity acts as a digestive sac. Growth rapidly takes place, and the gonophore may attain a considerable size, and is now absolutely identical with one of those organisms known as jelly-fish, or Medusæ. In fact, many of these "medusiform gonophores" of the permanently-rooted *Hydroids*

were originally described as a distinct order of free-swimming *Hydrozoa*. Finally, the essential elements—the ova and spermatozoa—are matured in the walls of the manubrial sac, between its endoderm and ectoderm, and embryos are produced. These embryos, however, do not develop into organisms like those that gave them birth, but into the fixed *Corynid* that gave rise to the gonophore.

The *Hydrozoa* are all aquatic, and mostly marine. They consist of simple and compound organisms, and, as a special terminology is in use with regard to them, it may not be inappropriate to explain some of the technical words used in describing them :—

Hydrosoma.—By this is meant the entire body of a *Hydrozoon*, whether simple, as a *Hydra*, or composite, as a *Sertularian*.

Polypite.—This term is given to the alimentary region of a *Hydrozoon*, *polype* being restricted to the same region in the *Actinozoa*.

Distal ; Proximal.—To the free-growing end of the Hydrosoma, near which the mouth is usually situated, the former term is applied, while the latter is given to the more slowly growing end, and that which is usually the fixed end.

Cœnosarc.—By this is meant the common trunk that unites the various polypites that make up a compound *Hydrozoon* into one organic whole.

Polypary ; Polypidom.—Either of these terms is given to the horny or chitinous outer covering with which many *Hydrozoa* are furnished.

II. ACTINOZOA (ἀκτιν, shore ; ζόον, animal ; most

animals belonging to this class are usually found at or near the sea coast). This class is composed of Cœlenterate animals that possess a differentiated digestive sac communicating below with the somatic cavity, but separated from the body wall by an intervening space (perivisceral), and divided into compartments by vertical partitions, or "mesenteries," to which the reproductive organs are attached.

Structure.—Their primary distinction from the preceding class is in their possession of the above-mentioned *differentiated digestive sac*; hence the body of a typical Actinozoon shows on transverse section *two* concentric tubes, one formed by the digestive sac, the other by the body walls; whereas, as we have seen, a similar section of a Hydrozoon shows but *one* tube.

Their fundamental tissues are like those of the Hydrozoa, an ectoderm and endoderm; the former, however, shows a tendency to be further differentiated into two others, corresponding with the derma and epidermis of man. Cilia are frequently present, especially in the interior of the somatic cavity. In some members of this class well-marked muscular fibres are developed. Thread cells, often of a complicated character, are nearly always present, and some Actinozoa can sting very severely.

Digestion.—Water containing nutrient matters is constantly made to circulate throughout the body cavity by means of cilia.

Circulation.—No traces.

Nervous System.—No traces.

Reproduction.—Distinct reproductive organs have been made out in all, but gemmation and fission is equally common with many members of this class.

The Actinozoa are both simple and compound organisms; some are free-swimming (Ctenophora), but many of them are permanently fixed throughout the whole period of their existence, and secrete a calcareous or horny framework, known as the "corallum," or "coral."

All known Actinozoa are marine.

Coral Reefs.—These are produced by the combined growth of several species of coralligenous Actinozoa; they are only found in latitudes where the mean temperature of the sea in winter is not less than 66°. They may be divided into three classes:—

(i.) *Fringing Reefs*: (ii.) *Barrier Reefs*; (iii.) *Atolls*.

(i.) *Fringing Reefs.*—These are not of great size, and either encircle islands or run along the shores of continents; they have no channel of any depth between them and the shore, and on the seaward side it has been found that they repose on gently-sloping surfaces.

(ii.) *Barrier Reefs.*—These also may either surround islands or skirt continents; they occur usually at a much greater distance from land, and there is usually a deep channel between them and the shore; soundings taken on their seaward margins show enormous depths.

(iii.) *Atolls* are nearly circular reefs, enclosing a central expanse of water; the reef is usually divided by one or more openings.

Coral reefs are in a great measure made up of dead coral. The coral-producing animal cannot live at a higher level than extreme low water, any exposure to the sun rapidly proving fatal; hence the way in which reefs are raised above the surface of the sea is by the denuding power of the breakers, which are constantly detaching portions and heaping them up in different places, where they become cemented together by the percolation of water holding carbonate of lime in solution; this is further rendered more secure against the future inroads of the sea by the vital activity of the living corals which form the seaward margin of the reef, and by their growth tend to restrain the sea from disintegrating the masses of sediment it may have thrown up.

The coral animals cannot live at a greater depth than 15 to 30 fathoms, so that no coral reef can be commenced on sea bottoms deeper than 30 fathoms: the formation of coral reefs that rise up from greater depths than this has been shown by Mr. Darwin to arise from a gradual subsidence of the foundation on which they had been commenced, and hence, in the case of *Atolls*, an island originally occupied the central lagoon; this, in the course of time, gradually became submerged, with the coral reef surrounding it, but the latter, owing to the living coral, during this subsidence was constantly growing upwards, and hence was enabled to maintain its relation to the surface of the ocean, and so, finally, were produced those curious lagoons in mid-ocean to which the above-mentioned name has been given.

Distribution of the Hydrozoa and Actinozoa in

—There are but few fossil remains of Hydrozoa; a curious impression in some Oölite formations has been thought by Professor Agassiz to be that of a Medusa.

The curious fossils known as Graptolites are most probably those of extinct Hydrozoa, and belong to the Silurian formations.

With respect to the distribution of the Actinozoa in Time, no other division of the animal kingdom is richer in fossil remains, with the exception of the Mollusca: in the Palæozoic rocks the division Rugosa seems to have filled the place now occupied by the Zoantharia, this latter only commencing about the Silurian epoch, and gradually increasing in numbers down to the present day, while the former slowly died out.

CHAPTER III.

Mollusca (*mollis*, soft).—This third division of the animal world consists of soft-bodied animals, nearly always provided with an exo-skeleton, or shell, and having *an alimentary canal entirely shut off from the general body cavity*. In this last respect we notice a distinct advance in specialization of function, comparing the Mollusca with those sub-kingdoms we have already described.

As we remarked when discussing the Cœlenterata, we there saw, in the imperfect attempts at differentiation, a foreshadowing of the higher condition at which we have now arrived, and from this time forth we shall find, in all animals with which we have to deal, an alimentary apparatus definitely separated from the rest of the organism, to which the function of nutrition is almost entirely relegated; the only apparent exception being found

in the case of certain parasites, that live by the absorption of the nutrient juices of their hosts. But in these the absence of an alimentary apparatus probably arises simply from the accident of their position; their remote ancestors not improbably may have possessed one, and gradually lost it through disuse, when they became degraded to the position of internal parasites, for it is a fixed law in organic life that disuse of any organ is invariably followed in time by its degeneration and decay; certain species, moreover, allied to some of these parasites, that lead a more honourable life, are found to possess distinct alimentary organs.

Circulation.—In this sub-kingdom we have the first appearance of a heart comparable with that of the higher animals; there is present nearly always some kind of propulsive organ by which the circulation of a hæmal fluid is maintained throughout the organism. The earliest type of a true heart is found among the Tunicata, and consists of a tube open at both ends, and the course of the circulation is periodically reversed. In the higher Mollusca we meet with a definite heart of two chambers, an auricle and a ventricle.

Respiration.—In the *Polyzoa* there is no distinct respiratory apparatus, but in the higher divisions of the Mollusca we find more or less differentiated respiratory organs

Nervous System.—In the higher Mollusca we always find a nervous system, consisting of three principal ganglia, known as (1) the cerebral or cephalic ganglion, (2) the pedal, (3) the parieto-splanchnic.

Sense Organs.—Organs of sight (ocelli) exist in many Mollusca, and in the higher form a distinct auditory organ is present.

Reproduction.—This is nearly always sexual, the only exception being in the case of the Polyzoa and social and compound Tunicata, where *gemmation* and reproduction by statoblasts often occurs.

The MOLLUSCA are usually divided into two divisions, (1) the *Molluscoida*, (2) *Mollusca proper.*

The former are characterized by the possession of but *a single ganglion*, or *only one* principal pair, and an imperfect heart; the latter have *three* principal pairs of ganglia, and a much more highly developed circulatory organ.

The following is a tabular view of the classes into which the *Molluscoida* and *Mollusca proper* are divided:—

MOLLUSCOIDA.	MOLLUSCA PROPER.
Class 1. *Polyzoa.*	Class 1. *Lamelli-branchiata*
,, 2. *Tunicata.*	,, 2. *Gasteropoda.*
,, 3. *Brachiopoda.*	,, 3. *Pteropoda.*
	,, 4. *Cephalopoda.*

1. POLYZOA (Sea-mats).—*Animals always in colonies.*

Structure.—The substance of body consists of an ectosarc and endosarc, the outer layer of the ectosarc corresponding with the *ecderon* of the Actinozoa, and developing into a testa or shell; the mouth is surrounded by a *lophophore** which is either circular or lycotropal (disc like), and bears tentacles, and opens into a dilated pharynx *capable of eversion,*

* A stage round the mouth, that bears the tentacles

and lined with cilia ; it is continued into a stomach and alimentary canal having a neural* flexure, and terminating in a distinct anus.

Digestion.—Nutrient matter is taken up from the water that is continually passing into the stomach.

Absorption.—By the walls of the alimentary canal.

Circulation.—A peculiar nucleated fluid known as "chylaqueous fluid" is present, perhaps connected with circulation, but there is no distinct circulatory organ of any kind.

Respiration.—By ciliated tentacles.

Secretion.—A mass of cells representing perhaps some form of liver is present.

Nervous System.—A single ganglion is situated between the anus and mouth.

Sense Organs.—Curious organs, known as "avicularia," resembling the beak of a bird, are situated between the zöoids of a Polyzoarium; these often have pointed processes (vibracula) attached to them, and are probably some kind of sense organ; their tentacles also may be considered as such.

Motor Organs.—The Polyzoa are mostly fixed organisms, but some of them (Cristatella) have the power of moving by means of a discoid foot, resembling that of the Brachiopoda.

---

* When the ganglion is situated on the side of the mouth, towards which the intestine turns in order to reach its termination, it is said to have a *neural flexure ;* when on the opposite side, the flexure is said to be *hæmal.*

Reproduction.—All are hermaphrodite, the ovary and testis being attached to the inner wall of the body cavity, the ovary uppermost. The male and female elements are liberated into the body cavity, and it is unknown how they escape to the exterior. Reproduction also frequently takes place by means of gemmation and statoblasts.

Development.—Oviparous.

2. TUNICATA (Ascidians).—*Solitary, Social, or Compound Animals.*

Structure.—An Ascidian resembles a two-necked jar; it consists of two walls or tunics, an outer (ectocyst) forming a coriaceous or cartilaginous tunic *containing cellulose*, and an inner (endocyst) forming a mantle, with a large number of contractile fibres.

Digestion.—The mouth, surrounded by tentacles, opens into a very dilated œsophageal chamber, *not capable of partial eversion*, continued into an alimentary canal with a *hæmal flexure*, and ending in an anus that opens into an "atrial chamber."*

Absorption.—General.

Circulation.—The first appearance of a true heart is seen in these animals; it consists of a tube open at both ends, by which a chylaqueous fluid is propelled through a set of vessels, first in one direction, then in the other.

* This is a large cavity or cloaca, in which the intestine and generative duct terminate, and by which these communicate with the exterior.

Respiration.—The water passes into the œsophageal chamber, which is lined by numerous vessels; thénce it passes into the atrial chamber, lined by a membrane which is reflected somewhat like a serous membrane over the pharynx, and ciliated openings exist between the two.

Secretion.—An organ somewhat similar to the pseudó-liver of the Polyzoa, consisting of yellowish cells, is usually present.

Nervous System.—A single ganglion is found between the anal and oral apertures.

Sense Organs.—Tentacles are always present; ocelli or pigment spots, and an auditory capsule are also met with.

Motor Organs.—Movements take place by means of the contractions of the mantle.

Reproduction.—Reproductive organs are present in the fold of the intestine, and the efferent duct opens into the atrial chamber.

Development.—Oviparous. The Salpa has a peculiar form of alternation of generation. A single Salpian produces a chain of embryos organically connected, and each embryo, by means of a statoblast, reproduces a Salpa.

3. Brachiopoda.—Aquatic animals with a bi-valve shell.

Structure.—Each valve is lined by an expansion of the integument; the animal is of small size, and the main mass inside the shell is made up of its arms, which are perhaps greatly developed lophophores.

Digestion.—The alimentary canal has a neural flexure, and may or may not end in a distinct anus.

Circulation.—Pseudo hearts connected with the lobes of the "pallium" or "mantle" have been made out, but these are probably excretory in function.

Respiration.—By means of cirriferous arms, which are probably homologous to the tentacular crown in the Polyzoa.

Secretion.—A granular secreting organ surrounds the stomach.

Nervous System.—There is a single ganglion between the gullet and the anus.

Sense Organs.—None.

Reproduction.—This has not been made out.

Development.—Oviparous.

Shell of Brachiopoda.—The valves are of unequal size (inequivalve), they are situated dorsally and ventrally, and in this respect differ from the Lamelli-branchiate shell, where the valves are situated laterally; these latter also have a projection known as the "Umbo."

MOLLUSCA PROPER.

1. LAMELLI-BRANCHIATA (animals with a bi-valve shell).

Structure (Oyster being taken as a type).—They are acephalous, and have a mantle which secretes the shells; these are kept apart by an external ligament, are lateral and equi-valve.

Digestion.—There is no odontophore present; the alimentary canal consists of an œsophagus, stomach, and intestine, with a neural flexure terminating in a distinct anus.

Absorption.—By veins.

Circulation.—The oyster has a heart consisting of two auricles and one ventricle, and the circulation is lacunar.

The rectum either pierces the ventricle or is embraced by it.

Respiration.—By plate-like gills which are ciliated (whence the name Lamelli-branchiate, from *lamella*, a plate; *branchia*, gills).

Secretion.—There is a racemose liver, and the Organ of Bojanus (this is a tube connecting the exterior with the somatic cavity).

Nervous System.—There are three chief ganglia, (i.) cephalic, (ii.) pedal, (iii.) parieto-splanchnic.

Sense Organs.—These are very deficient—eyes, and tentacles are situated round the edge of the body.

Motor Organs.—There is a distinct foot developed from the mantle, secreting from a furrow "byssus," and there are one or two pairs of adductor muscles.

Reproduction.—Unisexual.

Development.—Oviparous.

2. Gasteropoda.—There are two types of this order, the land Gasteropods (Pulmono-gasteropoda), of which the snail may be taken as a type, and the water Gasteropods (Branchio-gasteropoda), of which the whelk may be taken as a type.

Structure.—They are cephalic, that is, have a distinct head, and all secrete a univalve shell.

Digestion.—An odontophore is always present. There are generally two stomachs, and the alimentary canal may have a neural or hæmal flexure. The anus opens at the side of the neck.

Absorption.—By veins.

Circulation.—The heart has two cavities : an auricle and a ventricle. The course of the circulation is from the auricle to the ventricle, thence to the aorta, arteries, capillaries, veins, venous sinus, respiratory apparatus, back to the heart. The circulation in places is lacunar.

Respiration.—By lungs (saccular), or by gills (dendritic).

Secretion.—There are salivary glands, a large liver, Organ of Bojanus, and integumentary glands, that secrete a saliva-looking fluid.

Nervous System.—As in the Lamelli-branchiata.

Sense Organs.—Usually two pairs of tentacles, and an auditory vesicle.

Motor Organs.—There is a foot present, divided into propodium, mesopodium, and metapodium, a part of which latter (epipodium) secretes a structure known as the "operculum."

Reproduction.—Unisexual usually, but in the snail it is bisexual; here there is an ovo-testis which is tubular, and impregnation is mutual.

Development.—Oviparous.

3. Pteropoda.—So called from two wing-like appendages by means of which they swim (πτέρον, wing; πους, foot). *Cleodora* may be taken as a type

of this order. They are free and pelagic, but must be looked upon as inferior in organization to the Gasteropoda. They permanently represent the temporary (larval) stage of the sea-snails.

Structure.—They are cephalic, but the head is rudimentary, and bears the mouth, occasionally provided with tentacles and furnished with an odontophore. They may or may not possess a univalve shell.

Digestion.—A muscular stomach is present, and the flexure of the intestine is "neural," so that the anus is situated on the ventral aspect of the body. There is also a well-developed liver.

Circulation.—There is a heart of two chambers.

Respiration.—This is very rudimentary, the respiratory organ consisting of a ciliated surface which is either unprotected or contained in a branchial chamber.

Nervous System.—The ganglia are concentrated into a mass below the œsophagus.

Sense Organs.—There are rudimentary eyes.

Locomotion.—The true "foot" is rudimentary, and the "wings," by means of which the animal swims, are composed of the greatly-developed epipodia.

Reproduction.—The sexes are united in all.

Development.—The young pass through a metamorphosis, having at first a bilobed ciliated veil attached to the sides of the head.

4. Cephalopoda (types, Nautilus and Octopus).

Structure.—All segmentation is lost, the body is symmetrically constructed, and its exterior covered

by an exceedingly vascular mantle, which almost always secretes a shell. In the Nautilus the shell is polythalamic (many-chambered), and the animal lives in the last chamber, having lived in all by turns. All the chambers are connected by a "siphon," through which a distinct body process passes. The shell is principally composed of calcic carbonate, with a little calcic phosphate. The Cuttlefish has an endo-skeleton, the "pounce bone," a cartilaginous mass found free in a cavity at the back of the animal. In the Cuttlefish and Nautilus there is present in the head a ring of cartilage, containing on the circumference sense organs.

Digestion.—A pair of vertical jaws is present (Cuttlefish and Nautilus) constituting almost a beak, but the lower overlaps the higher one; in the mouth there is a fusion of the tongue and teeth (odontophore), consisting of a muscular tongue with transverse rows of teeth. There is an œsophagus, and two stomachs, one corresponding with the gizzard; and the intestine, which has a neural flexure, opens into the gill chamber.

Absorption.—By veins.

Circulation.—There is a central heart with one ventricle, and the course of the circulation is from the arteries to the capillaries, thence to the veins, venous sinuses, and gills. There are contractile vessels at the base of the gills corresponding to branchial or gill hearts. The branches of the cardiac vessels dilate before opening into the heart, and all have a lacunar circulation.

Respiration.—This is aquatic; water is introduced by a funnel on the inferior surface of the body

into a gill cavity. The gills are two in number in the Cuttlefish (Dibranchiate), four in Nautilus (Tetrabranchiate). The gills are dendritic and ciliated.

Secretion.—Salivary glands are present, and an enormous liver. There is also an organ opening into the intestine corresponding with the pancreas. The kidney (ink bag of Cuttlefish) opens into the gill cavity, as also into the alimentary canal. There are peculiar spongy masses round the veins. Integumentary or cutaneous glands are also present, probably pigmentary (Chromatophores,* muscular in nature, contractile, and therefore causing changes in the colour of the animal).

Nervous System.—There are three principal pairs of ganglia; the nerves given off from these have also ganglia on them. The cerebral ganglion is more concentrated and is protected by the ring of cartilage in the head, and in this respect approximates most nearly to the vertebrate type of organization.

Sense Organs.—Sight is very highly developed. There is no true eyelid present, but the skin over the eye is transparent. There is a "sclerotic," but no "cornea," an imperfect "choroid," and a "crystalline lens.' There is also a "retina," but no "aqueous or vitreous humour." There is a distinct auditory vesicle (labyrinth) connected with a cartilaginous ring.

Motor Organs.—A foot, consisting of propodium, mesopodium, metapodium, and epipodia. In the cuttle-

* χρωμα, colour; φερω, I carry.

fish the foot grows up round the mouth, and gives off prolongations (arms), which are eight to ten in number, of which eight are always alike, the remaining two being somewhat different. Each is a hollow muscular tube; there are suckers in its walls; and its extremity is furnished with a movable muscular piston, the fibres of which are circular, longitudinal and radiated. Blood vessels are never present in the centre of the tube.

Voice.—None.

Reproduction.—Unisexual. The ovaries and testes are tubular, and the genital aperture opens into the gill-cavity. The vas deferens, before reaching the genital aperture, dilates into a cavity in which the spermatic fluid collects; here the spermatozoa are collected into "Needhamian bodies;" these, in front are screw-shaped, and when discharged, work their way through the water to the genital aperture of the female. In the Pearly Nautilus one of the ten arms is detached, and with it the sexual apparatus (male), which swims like a "Needhamian body" through the water to the female. This was described by Cuvier, under the name of Hectocotylus, as parasitic on the female

Development.—Oviparous.

Distribution of Molluscoida and Mollusca in Time.—Remains of the Mollusca and Molluscoida are found abundantly in almost all the stratified rocks, from the commencement of the Silurian period up to the present day. The Brachiopoda were so numerous in the Silurian period that this epoch has sometimes been known as the "age of Brachiopods."

CHAPTER IV.

ANNULOIDA.—This sub-kingdom was proposed by Professor Huxley; it is closely related to the Annulosa, and by many considered as but a section of the latter. It derives its name from the ringlike (*annulus*, ring) shape of the body-segments of many of the animals composing it.

Structure.—Composed of numerous body-segments disposed radially round a longitudinal axis, provided with bilaterally disposed successive pairs of appendages. There is a distinct body cavity, from which the alimentary canal is completely shut off, and which, therefore, never communicates with the exterior through the mouth.

Digestion.—There is an alimentary canal, usually with a distinct mouth and anus.

Circulation.—A true vascular apparatus is sometimes present.

Respiration.—A peculiar system of tubes communicating with the exterior, known as the aquiferous or water vascular system, is present in all; otherwise, there is usually no distinct respiratory organ.

Nervous System.—There is a nervous system, composed of one or more ganglia with branches.

The ANNULOIDA are divisible into three sections: (i.) *Scolecida;* (ii.) *Echinodermata;* (iii.) *Rotifera.*

SCOLECIDA (examples: Distoma hepaticum and Tænia solium).—These include most of the parasites found in the alimentary canal of warm-blooded vertebrate animals; they especially frequent the epithelial lining of the respiratory and alimentary tracts.

Structure (Tapeworm).—Segmented, but not very distinct, and flat; the most anterior segment possesses "hooks" and a kind of "sucker." The liver fluke (Distoma) is not segmented.

Digestion.—There is no alimentary canal whatever in Tænia. The animal lives by absorption of the chyle of its host. In Distoma there is a mouth and dendriform intestine.

Absorption.—No absorbent system.

Circulation.—No circulatory system.

Respiration.—All have a water-vascular system (believed always to communicate with the exterior). In Tænia some six longitudinal vessels, ending in last segment in a contractile vesicle, communicating with the exterior, are present. In Distoma this system is a complex net work.

Secretion.—No secretory system.

Nervous System.—Two or three excessively small ganglia are found in the anterior part of the animal.

Sense Organs.—None.

Motor Organs.—There are traces of muscular fibre in Distoma and Tænia, but probably not used, except in the suckers of the former.

Reproduction (Tapeworm).—Bi-sexual and separate organs occur in each segment. Male organs consist of a very convoluted testis, female of an ovary separable into three parts; the centre portion secretes the germinal spot, and the lateral portion the yelk. The ducts unite into a common duct, opening on the exterior. The male and female organs open at the same orifice on alternate sides. Impregnation takes place by the animal bending on

itself so that two alternate segments come into opposition, then mutual impregnation takes place between them.

Development.—Oviparous. The last segment of a Tænia (proglottis) full of ova is discharged in the fæces of some warm-blooded vertebrate animal; the ova get dispersed in various ways, and possibly after a time get into the food of another animal of the same class. They are then swallowed, and in the alimentary canal of this latter become developed into what were known as Cisticerci (proscolices). In this condition they have two piercing hooks and four inverted ones, and by their means are enabled to penetrate the intestinal walls of their hosts, and to become encysted in a congenial habitat, usually the liver. Development can now go no farther unless the encysted worm (scolex) be again liberated, which may occur through the death of its host, when, if swallowed by a warm-blooded vertebrate, the scolex becomes developed into a mature Tænia.

This process is another example of the so-called alternation of generation.

The most familiar examples of the parasitic worms in man are the "Ascaris lumbricoides" (round worm), the little "Oxyuris" (thread worm) and the "Trichina spiralis." The first two inhabit the lower part of the alimentary canal and the ova* are expelled with the fæces, but not much is known of the subsequent development of the embryo. In the case of the Trichina, however, a regular process of development has been made out. This parasite is

* I have found the ova of thread worms occasionally on examining microscopically the dirt scraped from beneath the nails of children.

known in two conditions, as sexually mature and immature; in the latter condition it inhabits the muscles, usually of the pig, in vast numbers, each worm being encysted. If a portion of this trichinatous pork be eaten by a warm-blooded vertebrate animal an immediate development of young Trichinæ takes place. The immature worms, escaping from their cysts, grow and develop sexual organs; they then give birth to a numerous progeny, which they produce viviparously. The young Trichinæ, thus produced, perforate the walls of the alimentary canal, and after working their way among the voluntary muscles, become encysted. The severe train of symptoms, somewhat resembling rheumatic fever, that this migration of Trichinæ gives rise to in the animal affected, is known by the name of Trichiniasis. When once encysted, the worm, unless again swallowed by a warm-blooded vertebrate, is powerless for mischief.

2. ECHINODERMATA (examples: Sea-urchin, Starfish, &c.)

Structure.—The body of the Starfish has five rays; its exo-skeleton consists of a number of scattered particles of chalk on its dorsal aspect. In the Echinus there is a shell covered by a layer of body tissue (perisoma); the shell is made up of ten zones, five of which are broad and non-perforated, and are known as the "interambulacral zones"; while five are narrow, perforated, and known as the "ambulacral zones." Each zone is doubly connected by a zigzag line of articulation; and at the anal end of the shell each is terminated by a special plate; those terminating the ambulacral zones are called "ocular,"

as they bear the eyes, while those terminating the interambulacral zones are called "genital," being connected with the reproductive apparatus. There is one plate larger than the others, known as the "madrepore" plate. An Echinus might be represented by a Starfish with its rays turned up to a point and the interspaces filled in. In the Starfish the eyes are at the end of the rays, and the genital plates situated between the arms.

Digestion (Starfish).—The mouth is on the inferior surface of the body; there is an œsophagus and stomach extended into the arms, ending in cœcal extremities. The anus is on the superior surface of the body. The Echinus has five jaws (Lantern of Aristotle); each in shape is a triangular pyramid, the sides of which articulate with each other so as to form a circle; each is perforated by an incisor tooth, and is moved by muscles arising from five long arches at the edge of the shell.

Absorption.—There is no definite absorption, but only transudation of the food into the somatic cavity.

Circulation.—Sometimes there is a central, fusiform, contractile vesicle or heart, and a blood-fluid (chylaqueous) fills the body cavity.

Respiration.—There is a water vascular system (ciliated or contractile vessels containing water with air dissolved therein). The Starfish has a circular vessel in the centre, with radiating vessels down rays. This system is further modified for the purpose of locomotion, forming what is known as the ambulacral system.

Secretion.—A liver is present, and there are pits or follicles opening into the stomach.

Nervous System.—There is a ganglionated circular cord surrounding the gullet; three branches are supplied to each ray (Starfish); the central one accompanies the diverticulum of the stomach, and ends in the eye spot. The other two accompany the ambulacral system. The nervous system of the Echinus is on the same model.

Sense Organs.—The Echinus has tentacula, and also peculiar organs for grasping, known as "pedicellariæ." There are also rudimentary eyes.

Motor Organs (Starfish).—There is a set of vessels (aquiferous system), one central and two radial down each ray, which emerge by lateral slips through holes in the rays; these are known as the "ambulacral system," and terminate in a muscular sucker. By means of a small contractile vesicle near the extremity of the vessels, water can be forced into them so as to cause them to be protruded for a considerable length, and in that way to serve for locomotion. There is the same arrangement in Echinus; in addition there are double tubercles situated on the interambulacral zones, which carry spines articulated to the upper tubercle by a sort of "universal" joint, which serve for defence or locomotion.

Reproduction.—Unisexual. The sexual organs are in pairs. Impregnation takes place, not by copulation, but by diffusion of the reproductive elements through the surrounding water.

Development.—Oviparous. The egg bursts and gives forth an embryo, oval, and ciliated, swimming freely

by means of cilia ; in the next stage the cilia become restricted to certain zonular lines, being so arranged as to give bilateral symmetry ; next, bands of cilia become raised on certain projecting eminences ; formation of an alimentary canal then takes place with an angle in the middle, and there appears a mass of cells (blastema) ; after which involution of the dorsal integument takes place towards this blastema, forming a tube which at length ends in it ; the end of this becomes the central vessel of the water-vascular system of the adult. All the larval structures are next thrown off so as to leave the blastema with its radiating vessels free, and the adult is developed from this alone.

The above-mentioned involution of the dorsal integument begins where the "madreporic" plate is afterwards situated.

Differences between the Larvæ of Starfish and Echinus. In the former it is vermiform as described above, in the latter it is pluteiform,* and no ciliated extensions of the body take place as in the former.

3. Rotifera (Wheel-animalcules, very minute in size—never parasitic.)

Structure.—Most are entirely invisible to the naked eye ; their name is derived from the characteristic organ they carry, the wheel, or "trochal disc," which is always at cephalic end of the animal ; they are all aquatic and mostly free-swimming animals ; they are usually simple organisms, but sometimes form colonies. The female is much more developed than the male. Example of class Hydatina senta.

Digestion.—There is a mouth, that usually opens

* *Pluteus*, pent-house.

into a pharynx, or "buccal funnel," constituting the pharyngeal bulb, which often contains a complicated masticatory apparatus; the intestinal canal is usually a more or less simple tube extending through a well-developed perivisceral cavity, and opening into a dilatation or cloaca posteriorly, which forms the common outlet for the digestive, generative, and water-vascular systems.

Circulation.—There is no central circulatory organ, but the perivisceral cavity is filled with a corpusculated fluid.

Respiration.—There are no distinct organs of respiration, but there is a well-developed water-vascular system. Mr. Gosse thinks that this bears a close analogy to the renal system of the higher animals, and hence that "the respiratory and urinary functions are in the closest relations to one another."

Nervous System.—There is a cerebral mass, usually bilobate, placed anteriorly. This, for its proportionate volume, may be considered to compare favourably with the brain of the highest vertebrates.

Sense Organs.—Rudimentary eyes in the form of red pigment spots are found in connection with cerebral mass; also tactile organs in the form of two knobs, surmounted by tufts of bristles, placed at the back of the head.

Motor Organs.—"Trochal disc." There is a circlet of cilia at the cephalic end of the body, which vibrate so rapidly when in action as to give the impression that the entire disc is rotating. This disc is capable of inversion and eversion, and serves for the purpose of locomotion, acting something like the propeller of a screw steamer.

Reproduction.—There are conspicuous ovaries in the female, but the mode of reproduction is doubtful; in summer, the young Rotifers appear to be produced by the female without having access to the males.

Distribution of the Annuloida in Time.—Numerous remains of Echinodermata occur in most of the sedimentary rocks, beginning with the base of the Lower Silurian rocks, and extending up to the Kainozoic formations. With regard to the order Echinoidea, there is but one aberrant representative in the Palæozoic period; but the Mesozoic and Kainozoic formations are rich with their fossils.

The Asteroidea (Starfish order) range over a longer period, extending from the Lower Silurian period to the present day. Starfishes abound in the Oölitic formations (Mesozoic) and again in the Cretaceous rocks. In the Tertiary rocks (Kainozoic) but few are known to occur.

CHAPTER V.

Annulosa.—The members of this sub-kingdom have their body composed usually of definite segments, or "somites," arranged along a longitudinal axis. They are often provided with bilateral appendages (limbs), which are turned towards the neural aspect of the body. A nervous system is always present, consisting of a double chain of ganglia running along the ventral surface of the animal.

This sub-kingdom is usually divided into two sections—

(i.) *Anarthropoda* (*α*, priv.; ἄρθρον, joint; πους, foot), where the body is not provided with articulated appendages. (ii.) *Arthropoda*, where articulated ap-

pendages are present. To the former belong the Leeches, Earth-worms, Tube-worms and Sand-worms, and to the latter the Crustaceans, Spiders, Scorpions, Centipedes, and Insects.

The ANARTHROPODA are divisible into two classes—

(1) *Gephyrea*. (2) *Annelida*.

1. GEPHYREA Certain worm-like animals belong to this class, in which the segmentation is sometimes definitely marked, and sometimes not, but no ambulacral tubes or foot-tubercles are ever present, though there are sometimes bristles present that are subservient to locomotion.

The Sipunculus may be taken as a type of this class; it is a worm-like animal, which burrows in the sand of the coasts of most of our European seas, or inhabits the shells of dead Molluscs.

The *Gephyrea*, as a class, are not of great importance, but are interesting as connecting the Annulosa with the Annuloida, and have by some authorities been classified with the Echinodermata.

2. ANNELIDA. Orders—

(i.) *Suctoria* (Leech).
(ii.) *Dorsibranchiata* (Sand-worm).
(iii.) *Oligochaegta* (Earth-worm).
(iv.) *Tubicola* (Tube-worm).

Structure shows signs, but only signs, of segmentation. The segments are very numerous, and none (exc. Tubicolæ) have any exoskeleton. In Tubicola the tubes are secreted by the animal, but consist of agglutinated sand, &c., from the surrounding waters.

Digestion.—The mouth is at the anterior part of the body, but not at the extremity, and jaws are

present, which are only hardened (calcified) mouth epithelium; their number is various, often very considerable; in position they are always lateral, and sometimes different on opposite sides.

The Leech has three jaws, semi-circular and serrated, which make about half a revolution in biting.

The alimentary canal has a large number of cæcal appendages (Leech); a second muscular stomach is present in some (Earth-worm), and there is always a distinct anus.

Absorption.—The food exudes through the digestive canal. There are no veins present.

Circulation.—There is blood, confined to the somatic cavity (chylaqueous fluid), but no distinct circulatory organ. Blood may be defined as any corpuscular and nutritive fluid which fluctuates through the animal by its movements.

Respiration.—Much respiration takes place by the general surface of the body.

Pseudhæmal System, is a respiratory system; it consists of a dorsal and ventral vessel (contractile), connected at their anterior or posterior end by a vessel or a network of vessels; this is full of a non-corpuscular aqueous fluid, which introduces air dissolved in water to all parts of the body. These vessels also may possibly communicate with the exterior.

The Leech has four pseudhæmal vessels, two of them being lateral; the Dorsibranchiata and Tubicolæ have branchial extensions of the body, containing, not blood, but the pseudhæmal fluid; and in the case of the former, the water over the

back, and in that of the latter, the water about the extremity of the body, is changed by the contractions of the branchiæ.

Secretion.—Hepatic and renal tubuli open into the alimentary canal. In the Leech there are segmental organs that secrete a lubricating fluid, and are therefore cutaneous glands. In all Annelida the segmental organs are tubes open externally and internally. These serve, among other things, as oviducts.

Nervous System.—This consists of cephalic and thoracic ganglia, the first pair being above the œsophagus, the rest below. The Leech has three ganglia in addition, supplying the jaws (called the "sympathetic system").

Sense Organs.—The Dorsibranchiata only have antennæ, and these are not jointed. All have ocelli, which are very simple and rudimentary. The Leech has ten ocelli.

A few members of the class may have an auditory vesicle.

Motor Organs (the Leech).—No limbs or appendages, but has two suckers, one anterior, and one posterior, the anterior containing the mouth.

The rest have "parapodia." There are two extensions of the body (notopodium and neuropodium) that carry bristles, or cirri—rather longer bristles.

Reproduction.—Bi-sexual generally, the ovary and testis being tubular; but the leech is unisexual.

Development.—Oviparous. There is no true meta-

morphosis, but a multiplication between penultimate and antepenultimate segments may take place.

We next come to the section Arthropoda, which consists of four classes : (1) *Crustacea*, (2) *Arachnida*, (3) *Insecta*, (4) *Myriapoda*.

1. Crustacea (type, Lobster).

Structure.—The body is made up of segments or "somites," and is divisible into three regions—the cephalic, consisting of six somites ; the thoracic, of eight ; and the abdominal, of six somites. The exo-skeleton is largely made up of chitine, strengthened by calcareous matter.

The head and thorax are covered by one continuous carapace, with a line of demarcation from the rest of the skeleton of the individual.

Digestion.—The jaws move horizontally, and are either hardened mucuous membrane, or modified limbs.

There are several pairs of these—(1) mandibles, in front ; (2) maxillæ, often two pairs (these are hardened mucous membrane) ; the rest are modified limbs (maxillipedes). There are three pairs of maxillipedes, bearing palpi, or feelers, and these correspond with the three pairs of limbs in Insecta.

An œsophagus is present, as also a stomach and intestine.

Absorption.—This is carried on by veins.

Circulation.—The blood has no trace of red corpuscles. The heart is situated in the dorsal region of the body, and consists of a square cavity, just under the carapace in the lobster. The veins end in venous sinuses on the inferior aspect of the body,

and pass from thence, through the gills, to the pericardium, and then to the heart. The heart sends out dorsal arteries forwards and backwards.

Respiration.—Aquatic, by gills. A gill is an extension of lining membrane for the purpose of breathing air dissolved in water. The gills are in a cavity under the carapace, connected with maxillipedes; the water is swept through the gill chamber from front to back by scaphognaphites,* attached to maxillipedes. There are no cilia.

Secretion.—The liver is still a racemose gland. Probably the kidneys are represented by two or three long tubes opening into the alimentary canal.

Nervous System.—On the ventral aspect of the body there is always a chain of ganglia, in pairs, connected by a cord. In all Annulosa the first pair is in the upper aspect, joined to a second pair by a pair of cords which wind round the œsophagus.

One pair of ganglia is, as a rule, furnished to each somite.

Sense Organs.—A pair of antennules (often two pairs), and also a pair of antennæ that are tactile organs. Distinct eyes that are pedunculate and compound, having quadrangular facets. (N.B.—In the Insecta these are hexagonal.) There is no tongue and no definite organ of smell. The organ of hearing is a short labyrinth, having a membrane (fenestra ovalis), a cavity containing fluid, and lined by nerve branches; otoliths also are present in it.

---

* A "spoon-like" modification of the second pair of maxillæ, by means of which the water is constantly being baled out of the gill chamber.

Motor Organs. *Appendages to somites.*

Cephalic—1. Eyes.
2. Antennules.
3. Antennæ.
4. Mandibles.
5, 6. Maxillæ.

Thoracic—1-3. Maxillipedes.
4. Chelate limbs.
5, 6. Forcepate limbs.
7, 8. Simple limbs.

Abdominal.—These somites all bear swimmerets, and the last segment forms a broad plate (telson).

Voice.—Not present.

Reproduction (Lobster).—Unisexual. Testes and ovaries tubular, and a penis is present.

Development.—Oviparous. They pass through a metamorphosis, but rather vaguely.

2. Arachnida (Spiders, Scorpions, &c.).

Structure.—Segmented. The segments of head and thorax are welded together to form a cephalo-thorax. In the spider the head consists of one somite, and the thorax of four, scarcely distinguishable, and the abdomen of only one. In the scorpion there is a cephalo-thorax and abdomen, long and segmented, containing a number of somites.

Exoskeleton.—Chitin, when present. In the spider there is a distinct cartilaginous endoskeleton = entothorax.

Digestion.—As in Insecta. Sometimes there are two pairs of maxillæ. They have an œsophagus, stomach, and highly complex intestine.

Absorption.—By veins.

Circulation.—As in Insecta, and there is a many-chambered, dorsal heart.

Respiration.—By lungs. (The only instance among the Annulosa.) The spider has tracheæ as well, but the scorpion breathes entirely by lungs, and the acarus entirely by tracheæ.

Secretion.—There are salivary glands, a liver as in Insecta, with tubular openings into the intestine; the kidneys also are tubular.

The spider has a sacculated gland (poison gland) in communication with the jaw, opening in the palpi. In the scorpion the sting, as in Insecta, is at the end of the abdomen.

The spinning gland of the spider is in the posterior part of the abdomen; there are some four or six spinnerets with an immense number of holes; the glands are tubular, and the hind legs plait the threads.

Nervous System.—As is usually the case among the Annulosa, but really there are only two pairs of ganglia to the cephalo-thorax; these supply cords, but no ganglia, to the abdomen. In the scorpion the abdominal cord is gangliated.

Sense Organs.—Antennæ are present, and sometimes antennules. The auditory organ, if present, is sacculated.

Motor Organs.—There are four pairs of legs (thoracic), and the muscles that move them are intrinsic.

Reproduction.—Unisexual. The testes and ovaries are tubular. The scorpion has a penis. In the spider the duct of the testis opens just between the legs on the under surface of the thorax; but a filamentous maxillipalpi is used as a substitute for a penis.

After impregnation the female always tries to kill the male. Her genital aperture is situated in the same position as in the male.

Development.—Oviparous ; no metamorphosis.

3. Insecta (Moths, Butterflies, &c.)

Structure.—Composed of somites ; one cephalic, formed by fusion of five or six, which carries the sense organs ; three thoracic, each carrying a pair of limbs, the last two often being furnished also with wings. The abdominal somites are nine in number, and the total number of somites are, therefore, thirteen. Any exoskeleton present is composed of chitin.

Digestion.—The mouth consists of an upper lip (labrum) and a lower lip (labium) ; there are two strong and hard mandibles, and two smaller and softer maxillæ ; the mandibles are often extended into palpi ; there are never any maxillipedes. An œsophagus, stomach, and in some a gizzard, are present ; sometimes, but rarely, a crop may be found ; there is also a long intestine.

Absorption.—By veins.

Circulation.—As in Crustacea, there is a dorsal heart, having several cavities.

Respiration.—Aerial ; in the abdomen are some nine pairs of apertures (stigmata), which open into air-tubes (tracheæ), ramifying all over the body ; and these are homologous to the spiral vessels of plants ; they are kept open by continuous spiral rings of chitin, homologous to tracheal cartilages.

Secretion.—Salivary glands are present ; there is always a liver, composed of tubuli, surrounded by a yellow adipose body ; there are also renal tubuli,

opening into the alimentary canal lower down, similar to hepatic tubuli in structure.

Sting.—It is formed by a modification of the azygos portion of the last segment, and consists of a sheath, a central piercing part, and lateral serrated organs; the poison is secreted by a tubular gland in the abdomen. The web of insects is secreted by a tubular gland, the duct of which opens in the labium.

Nervous System.—As in Crustacea.

Sense Organs.—Antennæ (generally one pair); compound eye, with hexagonal facets; some have simple eyes; the auditory organ is similar to that of Crustacea, and may be placed in any part of the body.

Motor Organs.—These are confined to the thorax. Two pairs of the wings, never more, are borne by the two last segments of the thorax (meso- and meta-thorax), and each thoracic segment has one pair of legs. The muscles are all-intrinsic.

Voice.—This is produced in various ways—in the cricket by friction of the leg against the elytron. Some have also "drums" (resonant chambers) in the abdominal somites.

Reproduction.—As in Crustacea, unisexual; testes and ovaries tubular.

Development.—Oviparous. The metamorphosis is divided into three stages—(1) Larva, or caterpillar; (2) Pupa, or chrysalis; (3) Imago, or perfect insect.

METAMORPHOSIS OF INSECTA.—*Larva.*—*Structure.*—Segments all of the same character, except perhaps the cephalic.

Digestion.—Mouth is simple, and furnished with two lateral horny jaws (probably the future mandibles); the alimentary canal is much longer than in imago, as the larva is a vegetable feeder.

Nervous System.—All the ventral ganglia are of the same size. The cephalic are not larger than the rest, and the thoracic are fused together.

Secretion.—The adipose body is specially present, and of larger size; it may be regarded as the formative material for the second and third stages; it becomes smaller as the animal passes through its metamorphoses.

Sense Organs.—They have no antennæ, and their eyes are simple, never compound.

Motor Organs.—Wings are never present; the legs are not confined to the thorax, but are furnished to nearly every somite (nine or ten pairs generally, sometimes more).

Reproduction.—They have not even the rudiments of sexual organs.

Pupa.—This is simply a quiescent stage, in which changes are going on.

4. Myriapoda (type Centipede. Properly this is a debased class of Insecta).

Structure.—There is no difference between the segments, and their number is much greater than twenty.

Digestion.—As in Insecta.

Absorption.—As in Insecta.

Circulation.—As in Insecta.

Respiration.—As in Insecta.

Nervous System.—The ganglia are not so well marked as in Insecta, otherwise they are similar.

Secretion.—As in Insecta.

Sense Organs.—There are no compound eyes, but often antennæ and antennules.

Motor Organs.—No wings, but many pairs of legs are present; often each segment has two pairs.

Distribution of Annulosa in Time.—Of the *Annelida* two orders only have left traces in the past. These are the Tubicola and Errantia: the former are recognized by their investing tubes, which are known to occur from the Silurian Rocks upwards; the Errantia are known by the tracks which they left upon ancient sea-bottoms, or by their burrows in sand; these are found in rocks of almost all ages, from the Cambrian period upwards.

The *Crustacea* are abundantly represented in the past, and their fossils are found in deposits ranging from the Cambrian rocks up to the present day. It is worthy of note that the more ancient forms approximate very nearly with the larval forms of their modern successors.

The *Arachnida* are but rarely found as fossils; both scorpions and spiders seem to have their beginning in the Carboniferous epoch.

The *Insecta* occur earliest as fossils in the Devonian rocks of America. These consist of the remains of Neuroptera; others have been found in the coal-measures. In the Secondary rocks fossil remains occur abundantly in some Oolitic and Liassic formations, and in some Tertiary strata Lepidoptera have been found in a good state of preservation. All fossil remains seem to be those of extinct species.

Fossils of the *Myriapoda* have been found as early as the Carboniferous epoch. The occurrence of air-breathing articulate animals (both Arachnida and Myriapoda) in the Carboniferous period is noticeable as being contemporaneous with the earliest known terrestrial Molluscs.

SECTION III.

VERTEBRATA.

CHARACTERS OF THE SUB-KINGDOM VERTEBRATA.—*Structure.*—A section of the body always shows two distinct cavities—a neural cavity, by means of which the main masses of the nervous system are protected and shut off from the rest of the body; and a hæmal, which is the representation of the single cavity seen on section through the body of an invertebrate animal. The structure known as the notochord is constant, as also the visceral arches and vertebral column.

Digestion.—Jaws and teeth are always present, the former working vertically and forming parts of the walls of the head; in the Invertebrata they are mere thickenings of the mucous membrane, or modified limbs. A mouth, œsophagus, stomach, and intestine are always present.

Absorption.—The presence of lacteals and lymphatics is a distinguishing characteristic of this sub-kingdom.

Circulation.—All Invertebrata, except the Amphioxus, have valvular hearts; a portal circulation is always found, and the blood always composed of red and white corpuscles.

Secretion.—A pancreas and spleen is constant, neither of which organs occur in the Invertebrata.

Nervous System.—There is always a brain and spinal cord (except Amphioxus), and the brain always has three divisions.

Motor Organs.—There are never more than four limbs, and these always have an internal skeleton.

Reproduction.—This is always unisexual.

Development.—Laminæ dorsales and laminæ ventrales are always present.

As the nearest approach to a connecting link between the invertebrate and vertebrate sub-kingdom may perhaps be found in the Amphioxus, the only living representative of an order (Pharyngobranchii) that may have been far more numerous in past time, a short account of this curious animal may not be out of place.

The *Amphioxus lanceolatus*, or Lancelet, is a singular little fish found burrowing in sandbanks in the Mediterranean. Its body is pointed at both ends; it has no exoskeleton and no osseous tissues whatever; it has a persistent notochord, but the rest of the body is membranous; its mouth is beneath and behind the anterior part of the body, and is surrounded by a cartilaginous ring, also extended into processes round it. The mouth leads into an extraordinary dilated pharynx ciliated throughout; its heart is a single cavity, somewhat tubular and without any valves. The blood, which consists only of white corpuscles, passes off through the branches, distributed over the pharynx in a network, which unite above into a large dorsal aorta; at several parts of the body there are contractile spaces in the

vessels. It has no gills, but respires by means of the pharynx; this is perforated, the holes being lined with cilia, and water passes in at the mouth through these holes into the somatic cavity, and is finally discharged through the abdominal pore. The only organ of secretion present is a doubtful liver, and its nervous system consists of a spinal cord with a slight dilatation at its anterior extremity. For motor organs it has dorsal and caudal fins only. It reproduces itself by means of certain thickenings of the abdominal walls, which are either ovaries or testes, and the ova and spermatic fluid are discharged through the abdominal pore.

The VERTEBRATA are usually divided into three divisions. (1) *Ichthyopsida*; (2) *Sauropsida*; (3) *Mammalia*.

The first division is made up of the two classes *Pisces* and *Amphibia*, and is characterised as follows:— Gills are always present at some period of their existence; the amnion is always absent, and the allantois found only in a very rudimentary condition. The blood corpuscles are red and nucleated.

In the second division (Sauropsida), which includes the two classes *Reptilia* and *Aves*, gills are always absent; the amnion and allantois are constant, and the skull articulates with the vertebral column by means of one occipital condyle; the articulation of the lower jaw with the skull takes place through the intervention of a "quadrate bone;" the blood corpuscles are red and nucleated.

In the third division (Mammalia) the amnion and allantois are constant, the skull articulates with the vertebral column through two occipital condyles, and

the lower jaw articulates directly with the skull without the intervention of a "quadrate bone;" there are also special glands (mammary) for the nourishment of the young, and the blood corpuscles are red and non-nucleated.

CHAPTER I.

ICHTHYOPSIDA—

	Pisces.	*Examples.*
Order (1)	*Dipnoi.*	(Lepidosiren).
(2)	*Teleostei.*	(Most fish).
(3)	*Ganoidei.*	(Sturgeon).
(4)	*Elasmobranchii.*	(Shark).
(5)	*Marsipobranchii.*	(Lamprey).
(6)	*Pharyngobranchii.*	(Amphioxus).

Structure:—

Exoskeleton.—Scales, which are of different kinds, and may be usually reckoned under two divisions: (1) With enamel, *Ganoid*, continuous over body; *Placoid*, scattered irregularly. (2) Without enamel, *Cycloid*, circular; *Ctenoid*, comb-like.

Endoskeleton.—Vertebræ only, which are dorsal and caudal. The bodies are amphicœlous, and have well-developed neural arches, and, in the caudal portion, well-developed hæmal arches. The number is extremely numerous, and the ribs are not attached to transverse processes. There is no sternum, except a dorsal one sometimes.

The anterior limbs, which are the ventral limbs, have a distinct arch, viz., coracoid, clavicle, and scapula, except the Ganoidei and Elasmobranchii, which have no clavicle. There are no further homo-

logous bones, only simple supporting bones for the rays.

The posterior limbs have a triangular bone representing the os innominatum.

Skull.—There are four kinds :—

(1) *Membranous.* (As in Amphioxus).
(2) *Cartilaginous.* (As in Marsipobranchii).
(3) *Cartilaginous.* With ossification in membrane (Ganoidei).
(4) *Cartilaginous.* With ossification in membrane and cartilage (Teleostei).

There is one occipital condyle, a well-ossified basi-occipital, a parasphenoid, and two vomers, which coalesce behind. The roof of the skull is formed by the supra-occipital, which corresponds to the squamous portion of the human occipital bone. The two parietal bones are very small; there is also an ethmoid (corresponding with the middle portion of the human ethmoid), and two præfrontal bones.

The upper jaw consists of præmaxillæ, very large, bearing teeth, and maxillæ behind.

The lower jaw consists of a mandible, and is divided into three portions: (1) Dentary portion; (2) Angular; (3) Articular.

The jaw-suspensorium corresponds with the os quadratum, and is attached to the hyoidean apparatus, which consists of a hyoid bone, with two cornua and five pairs of branchiæ posteriorly. The posterior branchial arch (hypopharyngeal bones) bears teeth.

Digestion.—Almost all have teeth, but in their distribution these are not confined to the mandibles, but are found in the vomer, palatine, and branchial

arches, maxillæ, and præmaxillæ. They are always anchylosed to the jaw, and not socketed. An œsophagus, stomach, small and large intestine are present. In Elasmobranchii there occurs a "spiral valve" (almost peculiar to the shark), and all, except Teleostei, have a cloaca.

Absorption.—There are no villi, but a network of lacteals is present. These have no valves nor glands, but communicate with the veins to a large extent.

There are two thoracic ducts.

Circulation.—In position the heart is inferior and anterior, and has a pericardium; it contains two cavities, an auricle and ventricle with valves between. The course of the circulation is from the ventricle to the three arches on each side, and through the gills; the branchial veins unite into a dorsal artery, giving off branches, thence into four veins (descending = jugular, ascending = cardinal). Each side unites into Cuvier's duct, and joins with the hepatic vein to make a venous sinus, which opens into the auricle. There is a separate portal system to the kidneys.

Respiration.—Always aquatic; by gills, which are bony arches covered by the mucous membrane, continuous with that of mouth. The gills are covered by an operculum, which represents the pinna of the human ear.

In the shark there are five gill cavities on each side, in the lamprey seven; the gills are not ciliated.

The swimming bladder is the homologue of our lungs; it is placed on the surface of the vertebral column, and communicates with the œsophagus.

In Dipnoi (Lepidosiren) the swimming bladder is a true lung.

Secretion.—There are no salivary glands. A liver is present, but a pancreas only in pike, eel, ray, and shark.

The pyloric appendages open into a duodenum; this is very constant and peculiar to fishes.

There are two kidneys, which are mere Wolfian bodies, and no spleen. In Teleostei the ureters open into a distinct bladder.

Nervous System.—There is little difference between the spinal cord and brain in size. The brain consists of olfactory lobes, cerebral lobes, and optic lobes, with a cerebellum.

The optic lobes include the optic thalami and corpora quadrigemina, and the cerebral lobes include the corpora striata. There are no convolutions, no corpus callosum, nor pons Varolii.

Sense Organs.—*Touch* is almost absent; *taste* is slight, the tongue being but small; *smell* is also slight. In Marsipobranchii there is but one nasal sac, and the nasal cavity (except in Marsipobranchii and Dipnoi) does not communicate with the mouth. *Hearing* is not much developed, there being only a labyrinth, and no external or middle ear. *Sight:* there are no eyelids (except in Elasmobranchii), no lachrymal glands, but a complex crystalline lens, and a pecten.

Motor Organs.—Fins. Two pairs (corresponding to anterior and posterior limbs of higher animals), respectively pectoral and ventral, their position being usually constant. Azygos, or single fins, are all on the median line, and are known according to their position, as dorsal, caudal, and anal. They are supported by certain interspinous bones, fixed between

the spines of the vertebræ, that are really dermal in origin.

Voice.—None.

Reproduction—Unisexual. The *male* has two testes of ordinary structure, but rarely or never a penis, and coition only takes place in the case of the shark.

The *female* has several kinds of ovaries: in some cases these are sacculate, in others solid. The oviduct is sometimes in direct continuation with the Fallopian tube, sometimes not. In the Elasmobranchii two oviducts unite into a single cavity (uterus), and in this the ovum and uterus interdigitate, but there is no placenta.

Development.—Oviparous generally, but in Elasmobranchii ovo-viviparous, the eggs being partially developed in the uterus of the mother.

Neither amnion nor allantois is ever present.

	Amphibia.	*Examples.*
Order (1)	*Urodela.*	(Newt).
(2)	*Gymnophiona.*	(Blindworm).
(3)	*Batrachia.*	(Frog).

Structure.—No *exoskeleton*, except in Urodela, in which order some small cycloid scales are scattered over the skin. *Endoskeleton.*—Vertebral column procælous. In frog there are eight præsacral vertebræ, one sacrum, and two fused post-sacral vertebræ. These post-sacral are really an ossification of the sheath of the notochord, and known as the Urostyle.

In Gymnophiona and Urodela the number of the vertebræ is large and indefinite, and they have no ribs.

In the frog the transverse processes of the dorsal vertebræ are very long.

Skull (Frog).—Largely cartilaginous; there are two occipital condyles, the basi-occipital is unossified, and the frontal and parietal bones form the roof of the skull. The nasal bones are much developed; a parasphenoid is present, which is peculiar to Pisces and Amphibia.

Girdle bones are present which correspond with the ethmoid, and tempero-mastoid, which are peculiar to Amphibia. There is a well-developed præmaxilla and long maxilla.

A quadrato-jugal bone is present, which is formed by a fusion of the quadrate and malar bones.

The pterygoid bone corresponds with the pterygoid process of the sphenoid, and is largely developed.

Vomers are situated between the præmaxilla and parasphenoid, and there are also palatine bones.

The lower jaw consists of at least two pieces, and the hyoidean apparatus is connected with the os quadratum.

Upper Limbs (Frog).—The anterior arches are fused together. The clavicles and coracoids, small bones meeting in the middle line, are fused with the præcoracoids.

There is a scapula, a short sternum, and a glenoid cavity formed by a coracoid and scapula. There is a humerus, and the radius and ulna are fused into one bone. The carpus is rudimentary, and the metacarpus consists usually of four digits.

Lower Limbs.—The innominate bones are fused in the middle line anteriorly, making a disc at the symphisis. There is a well-marked acetabulum, a femur, and the tibia and fibula are fused. The oscalcis and astragalus are well developed, and there are four digits.

Digestion.—There are no teeth in the lower jaw, and those in the upper are anchylosed to the maxilla. An œsophagus is present, a single stomach, a small and large intestine, and a cloaca.

Absorption.—No intestinal villi, but there is a network of lacteals on the walls of the alimentary canal. These have no valves.

In the frog there are two pair of lymphatic hearts, one over the transverse process of the second vertebra, the other pair close to the hip joint. The anterior pair communicate with the jugular vein, the posterior with the sciatic. The portal system is divided between the kidneys and liver.

Circulation; Blood.—Corpuscles, red, oval, and large. They are also nucleated, and are accompanied by a large number of white corpuscles. The heart has two auricles and one ventricle.

Respiration.—Almost entirely aerial. In Urodela there are sometimes gills as well as lungs.

All Amphibia swallow air, and their lungs are but little divided. They also breathe more or less by the surface of the skin.

Secretion.—There are a large number of well-marked cutaneous glands; no salivary glands, but a liver, spleen, and pancreas; the kidneys are more Wolfian bodies than true kidneys. Two ureters empty into the cloaca. There is a distinct bladder, not connected with the urinary system: it is probably the remains of the allantois.

Nervous System; Brain.—The parts are on the same level (from before backwards). There are, as in Pisces, olfactory lobes, cerebral lobes, and optic lobes, and a very small cerebellum.

The pons Varolii and corpus callosum are absent. The spinal cord runs to the end of the spinal canal.

Sense Organs.—*Touch* is fairly well developed; *Smell*, as in Reptilia and Aves; *Hearing*, much as in Reptilia and Aves, but the middle ear is absent in Urodela and Gymnophiona; *Taste* well developed, long papillæ being present; *Sight* as in Reptilia, three eyelids, &c.

Motor Organs.—Batrachia have four limbs, the anterior pair being developed first, with web feet; the rest are as in Reptilia.

Voice (Frogs).—The arytenoid cartilages and vocal ligaments are well developed. Frogs have also pouches, like drums, in common with mouth, and it is by means of these that their croaking is produced.

Reproduction.—Unisexual. The female has two ovaries, which are always saccular, the oviducts being a little separated from the ovary: these open into the cloaca. The male has two testes but no true intromittent organ.

Development.—Oviparous. There is no amnion and no distinct allantois. No food yelk nor umbilical vesicle.

Structure of Tadpole.—At birth it is entirely fish-like, without scales: the vertebral column is amphicælous, and caudal vertebræ are present (rudimentary).

Digestion.—There are no teeth, but a kind of beak is present, of horny or calcareous nature, and the animal is graminivorous or herbivorous. The alimentary canal is long and convoluted.

Circulation.—As in Pisces; one auricle and one ventricle, the latter giving off three or more pair of

aortic arches (generally four), which supply the gill apparatus, and then unite into an aorta which supplies the body.

Respiration.—At birth it has no breathing apparatus; the gills first appear as external branchiæ, which are developed from the visceral arches. (These latter are produced by thickenings at the anterior part of the body wall, perpendicular to the body axis.) Then a fold of skin (operculum) grows up and leaves only one gill-cleft open; this is on the left side. The aortic arches supply the branchiæ.

Lungs are developed soon, and the branchiæ disappear gradually as the lungs increase in size. As the lungs appear the aortic arches become modified, as follows:—

The first pair	correspond	with the	carotid arteries.
,, second pair	,,	,,	aortic arch.
,, third pair	,,	,,	cutaneous arteries.
,, fourth pair	,,	,,	pulmonary artery.

Motor Organs.—It is born without limbs and with tail; the anterior limbs appear first, but are covered by opercula; the posterior appear as the tail diminishes.

Reproduction.—There is no sexual apparatus at birth.

CHAPTER II.

SAUROPSIDA—

	Reptilia.	*Examples.*
Order (1)	*Crocodilia*	(Crocodile).
(2)	*Chelonia*	(Tortoise).
(3)	*Lacertilia*	(Lizard).
(4)	*Ophidia*	(Snake).

Structure.—Exoskeleton.—Scales. The crocodile has bone under horny matter.

Endoskeleton.—Vertebræ, which are generally procœlous, and ribs articulating with the transverse processes; the regions of the vertebræ are generally well shown. The average number of cervical vertebræ is nine; dorsal, eleven or twelve; lumbar, six; sacral, two; and caudal, about thirty. There are vertebral and sternal ribs, and many have uncinate processes; no sternum is present in order Ophidia.

Crocodilia have some abdominal ribs corresponding with the transverse tendons of the abdominal muscles.

Limbs.—Upper arch consists of two clavicles (exc. *Crocodilia*), two coracoids and a scapula. *Lower arch.*—Most reptiles have ossa innominates, but these are not ossified together.

Skull.—There is one occipital condyle, and the sutures are well marked; the basi-occipital is well ossified, and the lower jaw articulates with an os quadratum not connected with hyoidean apparatus. There is no parasphenoid.

Each ramus of the lower jaw is divided into a dentary, angular, and articular portion.

In *Chelonia* the skeleton is almost altogether composed of two shells: (1) *Carapace*, which is superior; (2) *Plastron*, which is inferior. The marginal plates of carapace are epidermic; the central plates, five in number, are formed by fusion of eight dorsal vertebræ (2-9); the costal plates are much extended, and help to form the lateral plates of the carapace.

The *Plastron*, according to Huxley, is dermal in origin; it is generally considered to be a modified sternum.

Digestion.—The teeth in *Crocodilia* and *Lacertilia* have sockets; *Chelonia* have no teeth; *Ophidia* have poison fangs, and it is doubtful whether these are canines or incisors; they are either grooved or perforated, and in communication with a gland under the temporal muscle, so that the act of biting expresses the poison, which is not dangerous, unless it gets entrance into the blood.

There is an œsophagus, stomach, small and large intestine.

In *Crocodilia* there is a gizzard, and in all the alimentary canal opens into the cloaca.

Absorption.—As in Aves.—There are no villi in the small intestine; the lacteals form a network, and these are without valves. There are two thoracic ducts, and all have two or more lymphatic hearts. All have, also, a portal system.

Circulation.—Blood as in Amphibia. The heart consists of two auricles and one ventricle.

Course of the Circulation.—The venous blood goes into the right auricle, then into the ventricle, thence it passes into three vessels: (1) pulmonary artery, (2) left aorta, (3) right aorta (these last two unite in a common vessel). There are two superior venæ cavæ, and one inferior vena cava.

In *Crocodilia* there are two ventricles, that is, the septum in the single ventricle is complete, dividing it into two, and the left aorta springs from the right ventricle with the pulmonary artery. The two aortas unite close to the heart.

Respiration.—*Ophidia* have one lung (right); the lungs are but little divided.

Secretion.—All have salivary glands, a liver, gall bladder, spleen and pancreas. The kidneys are like those in *Aves;* there is no bladder (exc. *Lacertilia*, where it is formed by the remains of the allantois). All have two nasal glands and a cloaca.

Nervous System.—The ratio of spinal cord to the brain is very equal; the anterior lobe of the cerebrum alone is present, and there are no convolutions; there is only the median lobe of the cerebellum, and no pons Varolii nor corpus callosum.

In *Reptilia* the optic lobes (corpora quadrigemina) are distinct from the optic thalami.

Organs.—*Taste:* They have a well-developed tongue with papillæ. In *Crocodilia* the tongue is fixed to the front and sides of the mouth. *Smell:* They are always furnished with anterior and median nares; there is no cribriform plate to the ethmoid bone, and the nasal bones are cartilaginous. *Touch* is nearly absent. *Hearing:* No external ear; the membrana tympani is level with the surface, and there is only one bone (stapes = columella).

Ophidia have no middle ear, and the cochlea is straight.

Sight.—There are three eyelids, except in *Ophidia*, in which they are fused over the eye and immovable; the membrana nictitans has a special lachrymal gland, and the sclerotic has a circle of bone. Nearly all have a pecten.

Motor Organs.—All have usually four limbs, except

Ophidia. *Ophidia* walk on the sternal ends of the ribs, that are extended into buttons.

Reproduction.—This is unisexual. *Female* possesses both kinds of ovaries, and the oviducts communicate with the cloaca. *Male* has two testes of ordinary structure. *Ophidia* and *Lacertilia* have two penes external; *Chelonia* and *Crocodilia* have one internal.

Development—Oviparous (little or no albumen in egg). An amnion and allantois are present, but no placenta.

Voice.—All have vocal ligaments; thyroid and cricoid cartilages are fused into one, and the *Ophidia* have arytenoid in addition, fused with above.

Note.—The last three classes, viz., *Pisces*, *Amphibia*, and *Reptilia*, are put into one division by Professor Owen, and called by him *Hæmatocrya*, or *Cold-blooded Vertebrates*, on account of the comparatively low temperature of their blood. This arises from the free admixture of their venous and arterial systems, owing to their imperfect circulatory apparatus. In the two classes we are about to describe, viz., *Aves* and *Mammalia*, we shall find that the circulatory apparatus is more perfect, and hence the temperature of the blood is relatively much higher; these, therefore, are called by Professor Owen the *Hæmatotherma*, or *Warm-blooded Vertebrates.*

	Aves.	*Examples.*
Order (1)	*Saururæ.*	(Archeopteryx, extinct.)
(2)	*Ratitæ.*	(Ostrich.)
(3)	*Carinatæ.*	(Birds in general.)

Exoskeleton.—Feathers, equivalent to hairs in Mammals, developed from the papillæ.

Endoskeleton.—*Vertebræ* have their bodies flattened.

The number of cervical vertebræ is usually large; the dorsal are more or less anchylosed together, the number of the sacral is more or less indefinite, and there are generally from three to four coccygeal or caudal.

The ribs are attached to the bodies and the transverse processes; each has a vertebral and sternal portion connected by a joint.

Sternum is much developed, and has nine centres of ossification, one being for the *keel* (where pectoral muscles are attached).

Skull.—There is one occipital condyle and a well-ossified basi-occipital; the sutures are nearly lost. The *Lower Jaw* is compound, and each ramus is divided into a dentary, angular, and articular portion. It articulates with the skull by means of a quadrate bone, which is not connected with the hyoidean apparatus. *Upper Jaw.*—The intermaxillary bones form the chief part.

Limbs.—*Upper Arch.*—There are four clavicles, two on each side. One pair (os furculare) corresponds with human clavicle; the other, the coracoid bone, is represented by the coracoid process of the scapula in man. The scapula in *Aves* is small; there is a humerus, radius, and ulna, but the two last do not allow of much rotation. Often there is a "patella brachialis," corresponding with olecranon process of ulna in man. There are two carpal and two metacarpal bones, the last always fused at the top and bottom. *Lower Arch.*—There are two ossa innominata, separated in front, and, therefore, no symphisis pubis. There is a femur and patella (ostrich has two patellæ) and a tibia; the fibula, if present, is fused with the tibia The tarsus and metatarsus are

completely fused into one bone; it has posteriorly and inferiorly one process for great toe (hallux), and anteriorly three processes for digits, with (1), (2), and (3) phalanges in order.

Digestion.—There are no *teeth*, but a *horny bill* is present. They are furnished also with an *œsophagus-crop* (this is a non-digestive expansion of the œsophagus, and many birds have two); a *small stomach* (proventriculus) in which all the gastric juice is secreted; a *muscular stomach* (gizzard) consisting of two voluntary muscles radiating from two tendinous plates; a *duodenum*, *intestine*, and *cloaca*, this last being the receptacle for the urine and generative secretions, as well as the fæces.

Absorption.—There are villi in the intestinal walls, but few lymphatics and lacteal glands.

There are always two thoracic ducts, and usually two dilatations in those ducts like "lymphatic hearts," but without muscular fibres.

Circulation.—Is like that of *Mammalia*, with the following exceptions:—(1) The blood corpuscles are *oval* and *nucleated*; (2) the arch of the aorta turns to the *right*; (3) there are two superior and one inferior vena cava; (4) the external mammary artery is the largest in the body next to the aorta.

Respiration.—Always aerial by *lungs*; there is no *diaphragm*, and the lungs are often extended into the somatic cavity generally.

Secretion.—The majority have no *salivary glands*; the *liver* is well developed, and there are two *kidneys*, but with no distinction between their medullary and cortical portions. The *urinary ducts* open into the cloaca; there is no *bladder*, *pancreas*, nor *spleen*. No cutaneous glands are found, except the coccygeal

gland, which secretes the "uropygeum," an oily substance, especially in aquatic birds.

Nervous System.—There are no *cerebral convolutions*, and only the *anterior lobe* of the cerebrum is present; the *cerebellum* is enormously developed, and the cerebral lobes do not entirely cover it; the facial nerve is very small.

Sense Organs.—*Touch:* this is very deficient; *taste*, also, singularly deficient; the tongue is an extension of the hyoid bone. *Smell:* there is no perforated plate to ethmoid bone, and the turbinated bones are cartilaginous. *Hearing:* there is no *pinna* (the owl has some feathers representing the pinna). Only one bone, viz., the *stapes*, is present. *Sight:* all have *three eyelids*, the sclerotic being strengthened by bony deposit just behind the cornea. There is an extension of the choroid (pecten) into the vitreous humour in a series of folds.

Motor Organs.—The anterior limbs form wings.

Voice.—There are *two larynges*, a superior and inferior; the superior is like the human, but is not used; the inferior is situated at the bifurcation of the bronchi.

Reproduction.—Unisexual. The *female* has one ovary (left) which is solid; there is generally a long oviduct. The *male* has two testes, the left being the larger, and usually a penis.

Development.—Oviparous. There are an amnion and allantois, but no placenta.

Note.—The orders quoted at the commencement of the description of this class are those adopted by Professor Huxley; the more general classification is that of Kirby, and is as follows :—

		Example.
Order (1)	*Natatores*, or *Swimmers*	(Ducks, Geese, &c.)
(2)	*Grallatores*, or *Waders*	(Herons and Storks.)
(3)	*Cursores*, or *Runners*	(Ostrich.)
(4)	*Rasores*, or *Scratchers*	(Fowls, Pigeons, &c.)
(5)	*Scansores*, or *Climbers*	(Parrots or Wood Peckers.)
(6)	*Incessores*, or *Perchers*	(Ordinary songsters, such as Thrushes.)
(7)	*Raptores*, or *Birds of Prey*	(Eagles, Hawks, &c.)
(8)	*Saururæ*	(Extinct Archeopteryx.)

CHAPTER III.

MAMMALIA—

		Example.
Order (1)	*Primates*	(Man, Ape.)
(2)	*Insectivora*	(Mole.)
(3)	*Rodentia*	(Rat.)
(4)	*Cheiroptera*	(Bat.)
(5)	*Carnivora*	(Cat, Dog.)
(6)	*Hyracoidea*	(Coney.)
(7)	*Proboscidea*	(Elephant.)
(8)	*Ungulata*	(Horse.)
(9)	*Sirenia*	(Dolphin.)
(10)	*Cetacea*	(Whale.)
(11)	*Edentata*	(Sloth.)
(12)	*Marsupialia*	(Kangaroo.)
(13)	*Monotremata*	(Ornithorynchus.)

Structure:—Exoskeleton.—Generally hair, except in *Cetacea* and in *Armadillo*, which has scales. *Endoskeleton.*—Seven cervical vertebræ, thirteen dorsal and five lumbar, three to five sacral, and an indefinite number of coccygeal; there are arches on the inferior surface of the coccygeal vertebræ. There are thirteen pairs of ribs and always a sternum.

Superior Arch.—There is usually a scapula and clavicle on each side. (The *Cetacea*, *Ungulata*, *Edentata*, and *Hyracoidea* are without a clavicle.) There is a humerus, and radius and ulna, sometimes fused. The carpus consists of from five to eleven bones, the metacarpus of five, and the phalanges of fourteen.

Inferior Arch.—The ossa innominata are all fixed together; there is a femur, patella, tibia and fibula, the last two being often fused. The tarsus, metatarsus, and phalanges are as in man, except in the whales and seals, which want posterior limbs. The whales and seals have the anterior limbs covered in by integument, and the muscles also of the posterior limbs are retained.

Skull.—Much as in man. There are *two occipital condyles;* a well ossified basi-occipital, the sutures being well marked. The lower jaw articulates *directly with the temporal bone, and each ramus is in one piece.*

Digestion.—The teeth are in alveoli, and consist of incisors, canines, præmolars, and molars, except *Edentata*, which have only molars, and *Cetacea* have whale bone. There is an *œsophagus*, *stomach*, *small*

and *large intestine*. In many species the *cæcum* is much developed.

Horses have the *spiral valve*, which consists of a convoluted part of intestine round a central axis.

In Monotremata there is a cloaca, or rectum, that receives urine and generative secretions.

In Ruminant animals, which are often hunted animals, and hence require to swallow their food hastily, and before mastication, when the food is swallowed it passes into a side stomach and afterwards is regurgitated, and again masticated before descending into the true stomach. The ruminant stomach is somewhat complex, and is divided into four parts: (1) The *Paunch*, (2) *Honeycomb*, (3) *Omasum*, (4) *Reed*.

Absorption.—All have lacteals, lymphatics, and villi; there are two thoracic ducts. There are also lymphatic glands, and the lymphatic vessels are provided with valves.

Circulation; Blood.—The corpuscles are red, circular, and non-nucleated. *Heart* has four cavities, two auricles and two ventricles. In *Sirenia* the two halves of the heart are quite separated. In the *Seal* the foramen ovale is persistent in adult life. In all the aortic arch goes to the left side, and there are two venæ cavæ, one ascending and one descending, except in *Proboscidia*, which have two descending venæ cavæ.

The intercostal arteries and iliac veins are much reticulated in the aquatic mammalia, in order to retain blood before going into the lungs, as these animals only breathe intermittently.

Respiration.—Always aerial by lungs, and these latter are more subdivided than in *Aves*.

Secretion.—There are *salivary glands* universally, except in aquatic Mammals. The chief glands are the *liver* and *kidneys*, with well marked cortical and medullary portions, and *mammary glands*. All have a urinary bladder.

Nervous System.—There is a distinct *brain* and *spinal cord*, the brain being larger than the spinal cord.

Brain.—Component parts are not on the same level; there is a *corpus callosum* and a *pons Varolii.*

In the lowest orders there is only an anterior lobe, the higher have a middle lobe, and the *Carnivora* and *Primates* have a posterior in addition.

The lowest Mammals have also only the median lobe of the cerebellum.

Only three orders have convolutions; they are—(1) *Primates*, (2) *Ungulata*, (3) *Carnivora.*

Sense Organs.—*Touch:* there are papillæ of skin, except in *Cetacea.* *Taste:* all have circumvallate papillæ. *Smell:* the posterior nares open into the mouth; the ethmoid also has a *cribriform plate*, which is peculiar to Mammals. *Hearing:* as in man, except in *Cetacea*, where the meatus is capillary. All, except Monotremata, have an *Incus*, *Malleus*, and *Stapes.* *Sight:* there are *three eyelids*, the third being the membrana nictitans. The sclerotic is often strengthened with bone. The choroid is deficient in pigment in some animals; *e.g.*, cat.

Motor Organs.—As in man, except in *Insectivora*, which have much developed anterior limbs, with everted palms.

In *Cheiroptera* the anterior limbs form wings; these are formed by an extension of the phalanges with membrane (patagium).

Carnivora are unguiculate, that is, the ultimate phalanx has a claw on its superior surface, normally retracted.

Sirenia and *Cetacea* have fins, but with the ordinary bones included in the flap.

In *Marsupialia* the hind limbs are much developed.

Monotremata have webbed feet.

Voice.—This is produced in the superior larynx.

Reproduction.—Unisexual.

Male Organs.—Two testes, always external, except in *Monotremata*, *Edentata*, *Proboscidea*, and *Cetacea*, in which the testes are internal; and a penis.

Marsupialia have the testes anterior to the penis.

Female Organs.—There are always two ovaries, except in *Monotremata*, where there is only one.

Monotremata, *Marsupialia*, and *Rodentia* have a double uterus; and in all, except in *Primates*, the uterus has cornua.

Development.—All are viviparous, and have an *amnion* * and *allantois*, and all, except *Monotremata* and *Marsupialia*, have a *placenta*.

Hyracoidea and *Primates* have a deciduate placenta.

Ungulata, *Sirenia*, *Cetacea*, and *Edentata* have a non-deciduate placenta.

* The *amnion* and *allantois* are what are known as "fœtal membranes;" the former is a membranous sac that envelops the embryo, and contains the liquor amnii; the latter is a structure developed from the middle layer of the germinal membrane; it is a pear-shaped cellular mass, growing from the under part of the embryo, and eventually converted into a vesicle, which envelops the embryo in part or wholly; it is the organ whereby the blood of the fœtus is aerated. The greater part of the allantois, which is external to the body of the embryo, is cast off at birth, but a portion, which is internal, is

In Primates, Insectivora, Cheiroptera, Rodentia } the placenta is discoidal.

In Carnivora, Proboscidea, Hyracoidea } the placenta is zonular.

Among non-deciduate placenta are to be noticed the diffused placenta of the pig, and the cotyledonary placenta of the sheep.

Distribution of the Vertebrata in Time.—*Pisces*—These, as would be expected, furnish us with the first indications of vertebrate life on the globe, but the traces of their past life only occur at a comparatively late geological epoch. The earliest traces of fish occur in the Upper Silurian formations, and at this early period remains of fishes are found of nearly as high an organization as the *Elasmobranchii.* In the next geological epoch (Devonian or Old Red Sandstone) the remains of fishes have become so numerous that this period has been known as the "Age of Fishes," most of the species belonging to the order *Ganoidei.* This order began to lose its predominance about the commencement of the Mesozoic period, to be succeeded by the *Teleostei* that have attained their maximum at the present time.

The *Marsipobranchii*, *Pharyngobranchii* and *Dipnoi* have not left any reliable traces, but are probably of great antiquity.

---

converted into the future urinary bladder. As the classes Pisces and Amphibia are without these structures, they have been known as *Anamniota* or *Anallantoidea*, in contradistinction to Reptilia, Aves, and Mammalia, which have been termed *Amniota* and *Allantoidea*.

Amphibia.—The living orders of Amphibia are of very modern date, being wholly Tertiary or Post-tertiary. The extinct order, *Labyrinthodontia*, is usually assigned to the Carboniferous period.

Reptilia.—The geological record bears evidence of many extinct orders of this class, and these mostly occur in the Mesozoic and Kainozoic deposits. The most noteworthy of these were the *Pterosauria*, flying reptiles furnished with flying membranes (patagia), the largest species of which is calculated to have had wings measuring 20 feet from tip to tip, and the *Deinosauria*, which were terrestrial and carnivorous, having affinities both with the Aves and Pachydermatous Mammals.

The *Megalosaurus*, the largest species of this order, was an enormous carnivorous reptile, measuring between 40 and 50 feet in length.

Of the living orders of Reptilia, *Chelonia* are the most ancient, traces of these being found in the latter part (Permian) of the Palæozoic period. The other orders belong to the Mesozoic and Kainozoic periods, the order *Ophidia* being the most recent.

Aves.—Some doubtful footprints of birds have been found in formations assigned to the early part of the Mesozoic period, but it is by no means unlikely that these were made by bird-like reptiles. The first undoubted traces of birds occur in the middle Mesozoic period (Upper Oolites), and consist of the bones and feathers of the extinct Archeopteryx. All other remains belong to the Tertiary or Post-tertiary periods.

Mammalia.—The earliest traces of Mammals occur in the early part of the Mesozoic period. The oldest known Mammal (Microlestes antiquus) is found in the upper part of the Upper Trias, and is most

nearly allied to the *Marsupialia*, which is probably the most ancient order.

N.B.—It is worthy of note that at the present time the fauna of Australia is almost entirely Marsupial, and its flora is largely made up of Araucariæ and Cycadaceous plants; while in its seas we have the Port Jackson shark; and the Molluscan genus *Trigonia* is exclusively confined to its coasts. Geology teaches us that at the time of the deposition of the Stonesfield Slate (Lower Oolites) the fauna and flora of this country must have greatly resembled that of Australia of the present day; for we have in these deposits the remains of small Marsupials, together with the cones of Araucarian pines and fronds of Cycads; while at the same time spine-bearing fishes, like the Port Jackson shark, are abundantly represented, together with many species of the now exclusively Australian genus Trigonia.

THE END.

INDEX.

INDEX.

Bemrose & Sons, Printers, 23, Old Bailey, London: and Derby.